

BBC

PREVIOUSLY BBC FOCUS MAGAZINE

Science Focus

WHAT YOU DON'T KNOW MIGHT HURT YOU

An essential
GUIDE TO LIFE ON MARS

The ethics of creating
MONKEYS WITH HUMAN GENES

The new tech
TAKING ON DEEPFAKES

NO MORE PAIN

Have we found the
off-switch for suffering?



IN THIS ISSUE

Race Science

Angela Saini on how
racism is creeping
back into science

Notre-Dame

How faithfully
can we
rebuild it?

Productivity

Do Silicon
Valley's health
hacks work?

Cancer

The promising
treatment made
from breast milk

Animal Behaviour

Tool use in the
natural world

FIM Enel MotoE™ World Cup



ENERGICA

SINGLE
MANUFACTURER

motoe™



The future is Electric...



* Energica Motor Company reserves the right to substitute or change design due to sponsorship.



ENERGICA

#MyElectric 100%
100% PERFORMANCE, 0% EMISSIONS. ELECTRIC

The future is NOW



ENERGICA EGO SPORT BLACK*

©2019 Energica Motor Company

Ride it NOW at energicamotor.com

CONTENTS

REGULARS

08 EYE OPENER

Incredible images from the world of science.

10 THE CONVERSATION

What's been in our inbox this month.

13 DISCOVERIES

All the latest science news and discoveries. This month: an end to AIDS is in sight; tiny ancient human discovered; great white sharks are scared of orcas; Marsquake detected, and much more.

28 REALITY CHECK

Find out about the science behind the headlines. This issue: how will Paris rebuild Notre Dame? Have Chinese experiments on monkeys gone too far? Is Silicon Valley style 'biohacking' the key to better performance?

34 SUBSCRIBE TODAY!



Save 30% and get a copy of the book *Our Planet*!

55 MICHAEL MOSLEY

Love to roll into bed at 2am and then get up for work at 6am? It might be time to consider an early night with a cocoa...

56 ALEKS KROTKOSKI

Many of us are quite prejudiced towards those who enjoy online gaming. But the truth is, the hobby can offer a lifeline to some people.

79 Q&A

Is there a science question you'd like answered? Our resident panel of experts have you covered!

89 RADAR

Your guide to this month's essential science, television, radio and books.

97 NEXT MONTH

Have a sneak peek at what's in the next issue of *BBC Science Focus*.

97 CROSSWORD

Give your brain a workout with our tricky cryptic crossword.

98 A SCIENTIST'S GUIDE TO LIFE

Got the conversational skills of a used teabag? Master the gift of the gab with our expert advice.

23 DISCOVERIES



A Marsquake has been detected on the Red Planet for the very first time.

28 REALITY CHECK

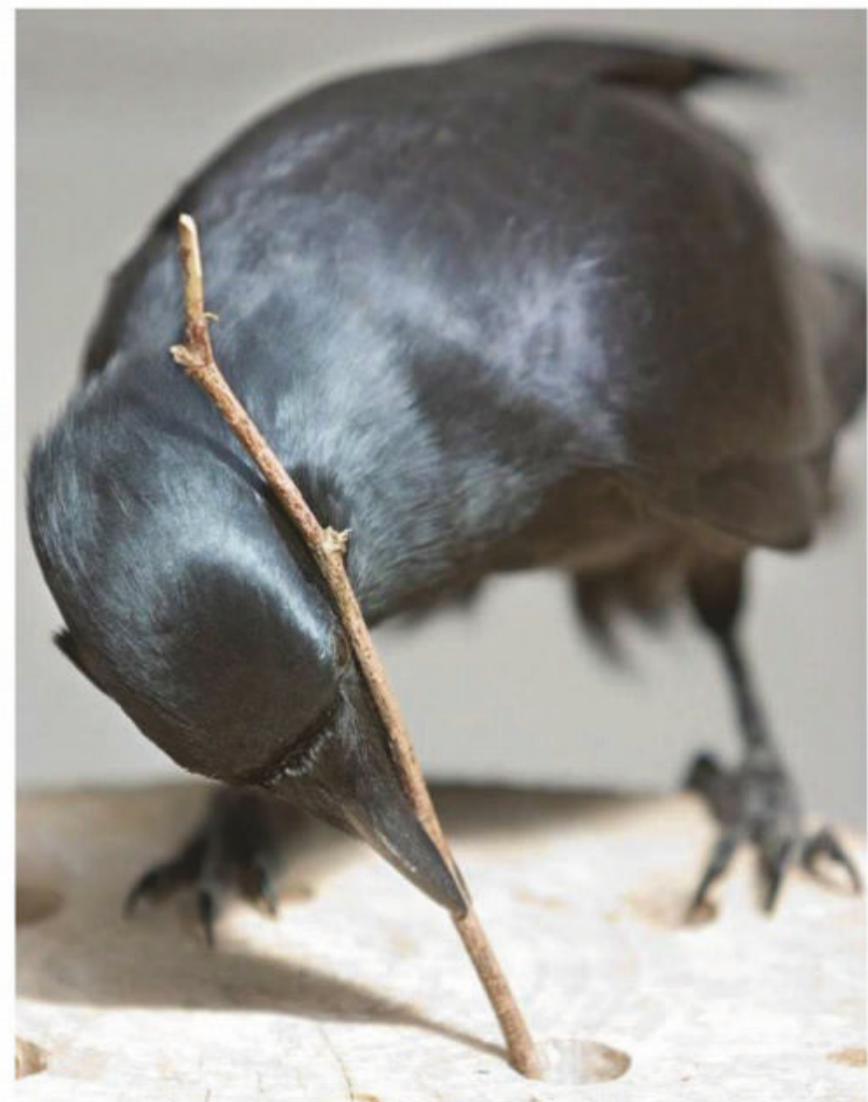


The world watched in shock as Notre Dame burned earlier this year. Can modern tech rebuild it?

39

THE SHARPEST TOOLS

Meet the Caledonian crow. It's not bird-brained, as it turns out.



FEATURES

36 THE SHARPEST TOOLS

We think we're pretty smart, with our knives and forks. But other animals can use tools to get food too.

42 NO MORE PAIN

Some people have never experienced the misery of a stubbed toe, or the agony of a broken limb, and they could help unlock a cure for those living with chronic pain.

48 RACE SCIENCE

Angela Saini reveals that racism is still an issue in science – in fact, it seems to be on the rise.

64 THE FIGHT AGAINST DEEPFAKES

Next generation artificial intelligence is threatening to take internet fakery to a dangerous new level.

70 LIFE ON MARS

Does the Red Planet harbour life? Here's what we know...

**70
LIFE ON MARS****42
NO MORE PAIN****48
RACE SCIENCE**

“[Race] has become embedded within the scientific method, within the structures of science and the way we categorise people”

WANT MORE?

Don't forget that *BBC Science Focus* is also available on all major digital platforms. We have versions for Android, Kindle Fire and Kindle e-reader, as well as an iOS app for the iPad and iPhone.



Can't wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied.

sciencefocus.com

**SPECIAL ISSUE**

ON
SALE
NOW

**BIG IDEAS IN SCIENCE
SIMPLY EXPLAINED**

In this special issue from *BBC Science Focus*, get your head around some of the most cutting-edge ideas in science, including wormholes, quantum physics, Schrödinger's Cat, deep learning, and the human microbiome.

[buysubscriptions.com/
focuscollection](http://buysubscriptions.com/focuscollection)

LOSE YOURSELF IN A WORLD OF

Vinyl

FIND YOURSELF IN
OXFAM'S ONLINE SHOP

oxfam.org.uk/shop



OXFAM

FROM THE EDITOR



Many of my earliest memories are painful ones. There's the time I bloodied my nose head-butting a rocking horse, the time I burned my finger touching an iron or the time I took half the skin off my forearm learning to ride my bike. Pain is a great teacher and so these days I keep away from rocking horses and hot irons, and do my best to stay vertical whenever I ride my bike. But what would have happened if none of those accidents had hurt me?

That's a question that a few hundred people might be able to help answer: they have a genetic glitch that effectively renders them unable to feel pain. It's an incredible twist of nature that has drawn scientists to their genome, who hope to find a way to help people who live with chronic pain. But how has it affected those who live with the condition? What happens when you can't be hurt, physically... or even emotionally? Enjoy the full story on p42.

Also in this month's issue you can find our reader survey. We want to hear your views on the magazine and its new look. So turn to p77 or visit sciencefocus.com/readersurvey to give us your feedback and you could be in with a chance of winning one of four Amazon prize vouchers, worth £100.

Daniel Bennett

Daniel Bennett, Editor

WANT MORE? FOLLOW SCIENCEFOCUS ON [FACEBOOK](#) [TWITTER](#) [PINTEREST](#) [INSTAGRAM](#)

ON THE BBC THIS MONTH...



BBC Sounds
Dr Kevin Fong tells the dramatic story of how the Apollo 11 mission was narrowly saved from disaster. *13 Minutes To The Moon* is available to download from bbc.co.uk/sounds

Radio

BBC Radio 4's *All In The Mind* delves into the psychology of motivation in a special episode recorded live at the Cheltenham Science festival. Hear the broadcast on 11 June.



TV

Brian Cox returns to our screens soon with his brand new series *The Planets*. Check *Radio Times* for details.



→ Ever heard a bird fart? Don't worry, the experts haven't either → p82

CONTRIBUTORS



DR STUART CLARK

Mars is alive with activity, but what about actual life? Astronomer Stuart takes us through the latest Martian discoveries and what they tell us about life in the Solar System. → p70



ANGELA SAINI

The author of *Inferior: How Science Got Women Wrong* reveals how misguided ideas about race have shaped the scientific agenda and the danger they pose. → p48



PROF CATHARINA SVANBORG

Immunology scientist Catharina is on the hunt for cancer-killing compounds. She talks to us about how she found them in human breast milk. → p20



DR SALEYHA AHsan

Being a doctor and TV presenter, Saleyha knows what it's like to be busy. She looks into the growing trend of hacking your health to become more productive. → p33

CONTACT US

Advertising

neil.lloyd@immediate.co.uk
0117 300 8276

Letters for publication

reply@sciencefocus.com

Editorial enquiries

editorialenquiries@sciencefocus.com
0117 300 8755

Subscriptions

bbcsciencefocus@buysubscriptions.com
03330 162 113*

Other contacts

sciencefocus.com/contact





EYE OPENER

Rusty water

GERMANY

Though this dark landscape might look like it's criss-crossed by rivers of lava, it's actually a highly polluted watercourse.

The vibrant colour of the river is down to iron hydroxide – the orangey-brown compound which gives rust its colour – and sulfate, which have run into the water as the result of coal mining.

When mining lignite – a soft, brown coal used for steam-electric power generation – the groundwater must be lowered, as moisture can damage the stability of the mine. This opens minerals such as pyrite to the air. Pyrite, often found in coal beds, is also known as fool's gold due to its metallic shine and colour. When exposed to oxygen and water, pyrite reacts to form sulfate and iron hydroxide.

TOM HEGEN

VISIT US FOR MORE AMAZING IMAGES:

SCIENCEFOCUS

BBCSCIENCEFOCUS



CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND BBC SCIENCE FOCUS

@ reply@sciencefocus.com
 BBC Science Focus, Tower House,
 Fairfax Street, Bristol, BS13BN
 @sciencefocus
 www.facebook.com/sciencefocus
 @bbcsciencefocus

LETTER OF THE MONTH

Magic of music

I recently read your article about dementia (May, p66). My wife was first diagnosed with 'early stage' Alzheimer's in 2012 and has gradually declined. She has been in a care home now for two years and sleeps the vast majority of the time, is totally immobile and incontinent, with reduced eyesight and hearing. The home is excellent with an 'outstanding' overall review from the Care Quality Commission, so I am lucky in that respect.

The reason for writing is that when I read that a recent House of Lords inquiry had taken place about the untapped potential of music with the intention that in 2020 a new campaign is to launch, I was genuinely shocked. The majority of good care homes use music already. When a patient reaches the later stages that my wife is now in, it is too late to help much. But her home has music

several times every week from visiting musicians, and is also in the process of putting onto computer the music that individuals once called their favourites, so that it can be played directly to them by headphones.

In addition to all that there are films, television, and dancing and drumming groups who attend, as well as animal visits from dogs to donkeys. So the benefit of music and other stimulation is well known, and up to a point it can be very beneficial to a patient with dementia.

Clive Lewis, Colyton

Thanks for sharing your story with us. Often scientists, and indeed policy, take time to catch up with what people working in these areas already know. This seems to be one example. That said, deeper understanding might eventually let us further help people with dementia.

Daniel Bennett, Editor

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a **Sphero BOLT** robot. Sphero BOLT provides endless opportunities to have fun while learning. It can be programmed with the easy to use Sphero Edu app, which helps you learn how to code. BOLT has advanced sensors like a gyroscope, accelerometer, and infrared communications, plus an animated LED matrix. sphero.com



WORTH
£150

Road rage

I have been a keen supporter of cycling for many years and am also a driver and pedestrian. In recent years, however, I have been disappointed by the antics of what appears to be a growing number of cyclists. They seem to consider that signs do not apply to them, and ride in such a selfish manner as to antagonise and frustrate other road and pavement users. They ignore traffic lights or swerve onto pavements to bypass them, pay no attention to pedestrian crossings and ride in a manner that makes passing them extremely dangerous. I could go on. I do think this minority group of cyclists bring of a lot of the anger against cyclists on themselves. They also put themselves and others in unnecessary danger by their selfish, self indulgent behaviour.

M Manley, Norfolk

As more cyclists take to the roads there will always be a contingent who won't follow the rules – as with any pursuit. But we have to be hopeful that these are a minority drawn to our attention by their behaviour. Besides, I suspect there are just as many irresponsible drivers on the roads as there are cyclists. I know which one I'd rather see more of!

Daniel Bennett, Editor

You wait for one bus

To reduce our negative impact on the planet, we all need to be

ON FACEBOOK

We posted some of our recent articles to Facebook, and you've been busy commenting.



@sciencefocus

Why is Leonardo da Vinci's scientific legacy so often overlooked?
bit.ly/sciencefocus_leo



@Nick Wallace

Total genius in all areas of his works. Incredible!



@sciencefocus

Caster Semenya: will limiting testosterone in female athletes make sport fairer?
bit.ly/sciencefocus_caster



@Richard Goodger

Either she is a woman or she is not. If she is a woman how is it even remotely fair to limit or redefine her nature to fit someone else's subjective idea of 'fairness'. Shall we bar all basketball players above 6'6" from playing? Ridiculous!



"I CUT MYSELF ALL THE TIME BUT YOU CAN BARELY SEE ANY OF THE SCARS. BUT I DO HEAL REALLY QUICKLY, WHICH IS STRANGE"

JO CAMERON, p45

using more public transport, but how do we make that appealing to people?

You really need the flexibility of a taxi combined with the efficiency of a bus service, all based on an electric vehicle. I thought about an idea that might work: it's called the Dynamic Bus Route. You go to your closest bus stop, the source, where you then enter a destination bus stop from a map. This could be any other bus stop in the city – so total flexibility. All of the routes go into a central computer. As source/destination requirements come into the central computer it is continuously generating the most efficient routes for all the buses and sending those to the drivers' sat navs. Everyone has a maximum known wait for the bus at their source bus stop and gets to their destination bus stop in a maximum known time limit. The question is, how do you figure out the feasibility of a new idea like this and whether it would work?

Andrew Cirel, via email

Funnily enough, this is a problem that many companies from Uber to Daimler to Google are working on right now. In a future where we no longer need to drive cars, we'll probably stop buying them. In this environment the company that can come up with the best algorithm to do what you've described – distributing a network of autonomous, electric cars around a city in a cost-effective manner – will rule



"THEY IGNORE TRAFFIC LIGHTS OR SWERVE ONTO PAVEMENTS TO BYPASS THEM"

the roads. The real question is, can we make it as cheap as public transport, or will it simply replace taxis?

Daniel Bennett, Editor

Shock tactics

I found the piece about Sir David Attenborough's new documentary deeply disturbing (April, p60). The spectacular scenery in their series, as well as other documentaries, gives a false sense of security to viewers that Earth is okay, which is pretty dangerous.

Over a mere 30 year period, I've witnessed an almost

complete decline of Red Sea reef ecosystems in coastal cities due to too much tourism. I strongly suggest that future filmmakers should adopt an alarmist attitude and show only unpleasant and ugly scenery.

Hatem A Tawfik, Cairo, Egypt

It's an interesting point, one that others share. But I wonder, would *Blue Planet II* have convinced so many people to change the way they use plastic if it had only portrayed the 'ugly' bits? Indeed, you can find the views of a marine scientist on this topic in the May issue's *Reality Check* feature (p36).

Daniel Bennett, Editor

THE TEAM

EDITORIAL

Editor Daniel Bennett
Production editor Alice Lipscombe Southwell
Commissioning editor Jason Goodyer
Online editor Alexander McNamara
Staff writer James Lloyd
Editorial assistant Helen Glenny
Online assistant Sara Rigby
Science consultant Robert Matthews

ART

Art editor Joe Eden
Deputy art editor Steve Boswell
Picture editor James Cutmore

CONTRIBUTORS

Hayley Bennett, Peter Bentley, Dan Bright, Stuart Clark, Charlotte Corney, Andrew Cotterill, Simon Crompton, Emma Davies, Russell Deeks, Alexandra Franklin Cheung, Alice Gregory, Alastair Gunn, Jules Howard, Mike Hughes, Jinhwa Jang, Christian Jarrett, Aleks Krotoski, Penny Lewis, Michael Mosley, Helen Pilcher, Dean Purnell, Jason Raish, Andy Ridgway, James Round, Helen Scales, Seth Singh, Luis Villazon, Joe Waldron, Elena Xausa

ADVERTISING & MARKETING

Group advertising manager Tom Drew
Advertising manager Neil Lloyd
Senior sales executive Anastasia Jones
Brand sales executive Sarah Smith
Brand sales executive Hannah Rich
Newstrade manager Helen Seymour
Subscriptions director Jacky Perales Morris
Direct marketing manager Kellie Lane

MOBILE

Head of apps and digital edition marketing Mark Summerton

INSERTS

Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION

Director of licensing and syndication Tim Hudson
International partners manager Anna Brown

PRODUCTION

Production director Sarah Powell
Production coordinator Lily Owens Crossman
Ad services manager Paul Thornton
Ad coordinator Jade O'Halloran
Ad designer Julia Young

PUBLISHING

Commercial director Jemima Dixon
Content director Dave Musgrave
Managing director Andy Healy
Group managing director Andy Marshall
CEO Tom Bureau

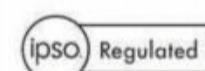
BBC STUDIOS, UK PUBLISHING

Director of editorial governance Nicholas Brett
Director of consumer products and publishing Andrew Moultrie
Head of publishing Mandy Thwaites
UK publishing coordinator Eva Abramik
Contact UK.Publishing@bbc.com
www.bbcstudios.com

EDITORIAL COMPLAINTS

editorialcomplaints@immediate.co.uk

ANNUAL SUBSCRIPTION RATES (INC P&P):
UK/BFPO £63; Europe & Eire Airmail £66;
Rest of World Airmail £70.



Audit Bureau of Circulations
50,022 (combined; Jan-Dec 2018)



BBC Science Focus Magazine is published by Immediate Media Company London Limited under licence from BBC Studios who help fund new BBC programmes.

© Immediate Media Co Bristol Ltd 2019. All rights reserved. Printed by William Gibbons Ltd.

Immediate Media Co Bristol Ltd accepts no responsibility in respect of products or services obtained through advertisements carried in this magazine.

MOW LIKE A PRO



TORO: THE FACTS

- PoweReverse™ – AutoMatic Drive System senses and delivers power to the front wheels to provide a **reverse assist** for easy manoeuvring.
- Enhanced comfort and control – the Iso-Flex™ handle is designed to float with a high/low range for **enhanced operator comfort** and control.
- Reduce storage space – the SmartStow® mower stores upright, **reducing the storage footprint** needed by up to 70%*.
- Recycle on Demand – quickly **switch from recycling to collecting** in seconds by flipping the quick-change lever.

Toro's residential lawn mowers are used and trusted by the professionals, so you can trust them to get the job done

Not all lawns were created equal. Some require more precision than others, which is why you need a mower you can trust for the extra tricky bits.

Toro's range of high-performance residential mowers boasts plenty of handy features that make even the most intricate jobs simple.

Thanks to its ingenious PoweReverse™ system, you can mow forwards and backwards seamlessly,

offering impressive power in both directions. This means no more tricky 10-point turns or caught wires.

And the precision finish Toro provides is why football clubs like Manchester United and Real Madrid, as well as prestigious golf courses such as St. Andrews Links, proudly use its machines on their hallowed turfs. When you choose Toro, you're choosing a range of mowers that is tried, tested and trusted by professionals, and that enables you to achieve that perfect finish for every single blade of grass in your garden.



To find your nearest dealer or request a brochure, visit toro.com/fm or call **0800 781 7153**

TORO

*compared to other Toro 55cm walk mowers



THAT'LL DO, PIG

Pig brains revived following slaughter p22

LONG-LIVED BATS

The winged mammals may hold the key to long life p16

KILLER WHALES

Great white sharks are scared of orcas p17

TINY RELATIVES

New ancient human species found in the Philippines p18

DISCOVERIES

An end to AIDS is in sight

Conclusive results of an eight-year study find that men on an antiretroviral HIV treatment have a zero risk of passing on the virus to sexual partners

An antiretroviral treatment developed by researchers at University College London (UCL) and the University of Copenhagen has reduced the possibility of passing on the virus that causes AIDS to zero.

The study, named PARTNER2, involved nearly 1,000 European gay couples in which one partner was HIV positive and the other HIV negative. Over the course of the eight-year study the couples reported having sex without the use of condoms nearly 80,000 times. None of them was found to pass on the virus to the HIV negative partner. The researchers ➤

AIDS ribbon structure in Durban, South Africa

Dino stomp Preserved tracks found in South Korea p15 **Breast milk** Human milk could help fight cancer p20
First-ever Marsquake Tremors detected by the Mars Insight lander p23

News in brief

HUMANS CAN SMELL WITH THEIR TONGUES

Humans can detect smells with their tongues, according to a study from the Monell Chemical Senses Center in Pennsylvania. Human taste cells contain a molecule which allows them to respond to smells as well as tastes.

It was long thought that the flavour of a food or drink was the result of the brain merging the smell and taste

inputs. This research suggests the two could be combined before they even reach the brain.

This unusual feature could be harnessed to encourage healthier eating: for example, by modifying a snack's smell, scientists could make it taste sweeter, so you can eat less and still satisfy your sweet tooth.



● estimated that based on the type and frequency of sexual contact, the treatment prevented around 500 HIV transmissions.

"Our findings support the message of the international U=U campaign, that a suppressed viral load makes HIV untransmittable. This message has been endorsed by more than 780 HIV organisations in 96 countries and can help end the HIV pandemic by preventing HIV transmission, and tackling the stigma and discrimination that many people with HIV face," said lead researcher Prof Alison Rodger, who is based at UCL's Institute for Global Health.

Antiretroviral drugs work by stopping a virus from replicating in the body, allowing the nervous system to recover and preventing further damage. The measure of the number of viral particles present in a given person's bloodstream is known as a viral load and is expressed as the number of copies of the virus found in one millilitre of blood. For anyone on antiretroviral treatment therapy the aim is to keep the viral load as low as possible.

In the PARTNER2 study, the treatment kept the viral loads of the HIV positive



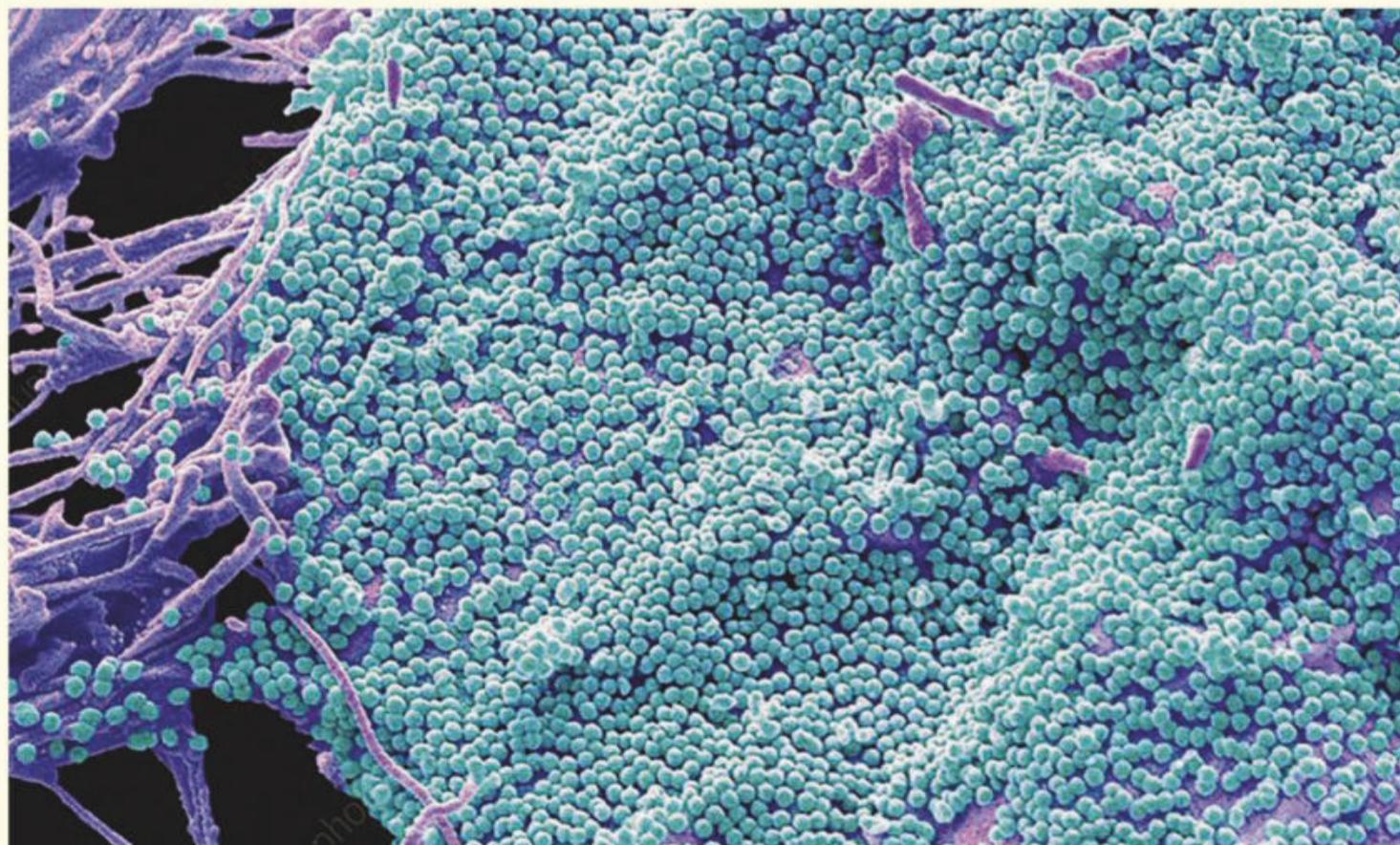
"The researchers estimated that based on the type and frequency of sexual contact, the treatment prevented around 500 HIV transmissions"

participants at fewer than 200 copies per millilitre, which is known as an 'undetectable viral load' and is the point at which the virus cannot be transmitted. When not on antiretroviral treatment, viral load amongst HIV positive patients can reach several millions.

"Increased efforts must now focus on wider dissemination of this powerful message and ensuring that all HIV positive people have access to testing, effective treatment, adherence support and linkage to care to help maintain an undetectable viral load," said Rodger.

For the latest science news, visit sciencefocus.com

Human cell (purple) infected with HIV virus (blue spheres)



WHAT ARE HIV AND AIDS?

HIV (human immunodeficiency virus) causes damage to cells in the immune system, weakening its ability to fight infection and disease. AIDS (acquired immune deficiency syndrome) is the name used to describe the potentially life-threatening illnesses that can arise when the immune system has been damaged by HIV. AIDS cannot be passed from one person to another, but HIV can be transmitted through unprotected sexual activity or the sharing of needles from an HIV positive to an HIV negative person.



SCHOOL BULLYING INCREASES THE RISK OF MENTAL HEALTH PROBLEMS

Being bullied in school can drastically increase your chance of developing mental health problems, according to a new study from Lancaster University. The researchers looked at data from 7,000 students aged 14 and 16, who were interviewed again

at 21 and 25. Bullying increased the extent of mental health problems at age 25 by 40 per cent. Plus, those who were bullied were 35 per cent more likely to be unemployed, and those who were working earned about 2 per cent less on average.

They did what?

Fish played video games

WHAT DID THEY DO?

A team at Bristol University projected a group of computer-generated 2D virtual prey onto one end of an aquarium housing a group of hungry sticklebacks, then monitored the fish as they mounted their attack.

WHY DID THEY DO THAT?

The researchers were interested in exploring how predatory fish target their prey, specifically where in a group of prey they choose to attack. By using virtual prey the team was able to precisely programme the movement patterns to ensure that there were no factors other than group position at play.

WHAT DID THEY FIND?

Prey at the front of the group were more likely to be attacked by the sticklebacks than followers situated in safer positions towards the group's centre. This means that leadership offers both opportunities and risks. Fortune may favour the bold when it comes to leaders influencing group decisions about what to do and where to go next, but lead fish will also be the first to run into any potential danger from predators. Further study could shed light on the evolution of leadership, the researchers say.



Impression of the dinosaur footprint, with tiny, visible scale marks

PALAEONTOLOGY

Exquisitely preserved dinosaur footprints discovered in South Korea

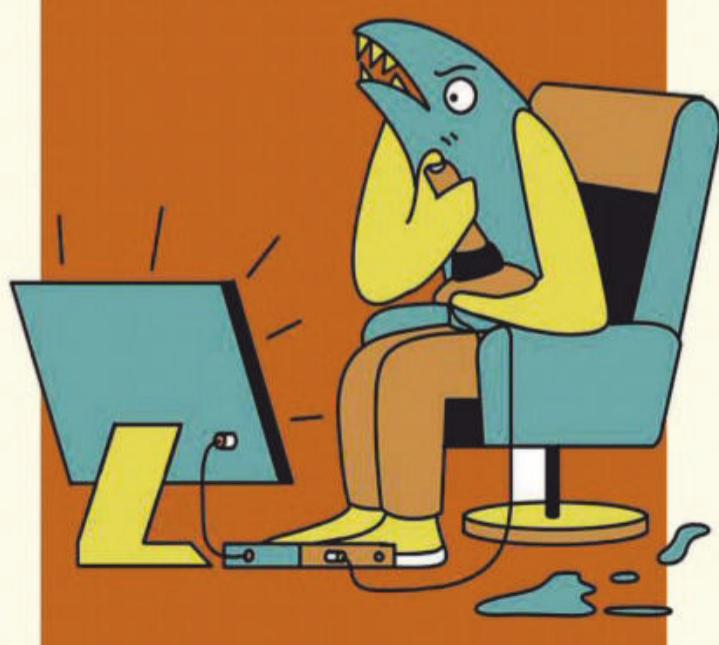
GETTY IMAGES X2, KS KIM, SCIENCE PHOTO LIBRARY ILLUSTRATION: ELENA XAUSA

A set of incredibly detailed dinosaur footprints has been uncovered near Jinju City, South Korea. The footprints are so well preserved that patterns of skin bumps are visible. This marks the first time that indentations caused by soft tissue, muscle and skin have been found over the entire surface of every track.

The tiny tracks were imprinted in the mud by a *Minisauripus*, a blackbird-sized theropod that lived 100 to 125 million years ago. It is thought that they are so well preserved due to the stickiness of the surface. Evidence shows that there had been a rain shower leaving water-drop impressions on the ground just before the tracks were made. In one place, the dinosaur

had stepped on a fresh raindrop mark, proving rain came first, and the dinosaur step came second. "These are the first tracks ever found where perfect skin impressions cover the entire surface of every track," said Prof George Martin Lockley of CU Denver, who co-authored the research. "The tracks were made on a very thin layer of fine mud, rather like a coat of fresh paint only a millimetre thick."

The researchers describe the texture of the skin of being like medium-grade sandpaper, but with the tiny scale traces arranged like woven fabric. Each scale measures less than 0.5mm in diameter and is similar to rare examples of mummified skin seen on the feet of ancient feathered birds found in China.





BATS COULD HOLD THE KEY TO EXTENDING HUMAN LIVES

Longevity is linked to body size, with larger species generally living longer than smaller ones. But some bats, such as the horseshoe bat, buck this trend and live for up to 40 years, at least eight times the average for mammals of their size. This ability may be linked to the bats' need to hibernate for long periods, according to a team at the University of Maryland. More research could unlock the secrets to extending lifespans.

Trending

YOUR GUIDE TO WHO'S SAYING WHAT ABOUT THE HOTTEST TOPICS IN THE WORLD RIGHT NOW

#beluga

It seemed something fishy was going on in the small harbour town of Tufjord, Norway when a group of locals came upon an unusually friendly beluga whale wearing a harness with the words 'Property of St Petersburg' written on it. This has led some to speculate that the whale may have been trained by the Russia army.



Dr Helen Scales

@helenscales

In 2017 Russian media reported that Soviet military bases in the Arctic were training captive Beluga whales to 'assist military divers and help kill enemy intruders'. So, it seems likely this one could be a defector from the Russian navy.

Sarah Durant

@SarahMDurant

This is why we need a Fifth Geneva Convention to safeguard wildlife and the environment at times of war - no state should be allowed to make wildlife agents of war #Beluga.



#Icecreamvanban

Several London councils have banned ice creams vans from their streets on the grounds that their diesel engines make a significant contribution to air pollution in the capital.

Mums For Lungs

@MumsForLungs

As we understand it, only the Mr Whippy needs the engine running. Idling vans are bad but that's a drop in the ocean compared to the scale of the #airpollution crisis. Let's see more #lowtrafficneighbourhoods and #schoolstreets please.

Beardly Weird

@BorgJonny

Brilliant, I'm all for small local businesses but they need to get up to speed. The environment HAS to come first.

#CasterSemenya

The South African 800m Olympic champion lost her legal case against the athletics governing body the IAAF. She will now have to take medication to reduce her testosterone levels to compete internationally at races between 400m and one mile.

Christian Munthe

@christianmunthe

Indeed. Semenya's testosterone levels is simply TALENT. #CasterSemenya #IAAF #sport #trackandfield

Julia Serano

@JuliaSerano

... seriously, by the same reasoning as the #CasterSemenya decision, every single athlete within the category of "men's" & "women's" sports should have their testosterone and other hormone levels medically adjusted to be within one or two decimal places of one another...



#extinction

A report published by the UN has estimated that one million species of plants and animals are now threatened with extinction, thanks to human activity.

Jane Goodall

@JaneGoodallICAN

UN Report's #GlobalAssessment says more than 1 million species of plants & animals are at risk of #extinction. But simple changes to our food & energy consumption can change that

Jess Phoenix

@jessphoenix2018

1 million species are on the chopping block. A quarter of all living things. The world in #AvengersEndgame is not an aspirational how-to guide, people. #extinction #science #environment

Dr. Jonathan Kolby

@MyFrogCroaked

I wish I could say this is surprising news, but it's not. For the past decade, we've been raising the alarm because a frog mass #extinction is already happening but little has changed #chytrid #scicomm

KEEP IN TOUCH



@SCIENCEFOCUS

In numbers

200,
000'

The number of populations of marine viruses found in the world's oceans as part of a pole-to-pole survey led by researchers at Ohio State University

23
million

The number of girls not born worldwide since 1970 due to sex selective abortions, as estimated by researchers at the National University of Singapore.

16

The number of minutes of lost sleep per night that can lead to increased stress levels, poorer judgment and worse workplace performance, according to a study at the University of South Florida.



ZOOLOGY

Who's afraid of the big bad orca?

Killer whales' taste for shark liver makes great whites flee in terror

Thanks to films like *Jaws*, it's widely assumed that great white sharks are the biggest badasses in the sea. But a study by researchers based at the Monterey Bay Aquarium in California has revealed that the title should probably belong to orcas. The study found that great whites are so terrified of orcas that they turn tail and flee whenever they encounter them, often not returning to the site of the encounter for several months.

And it seems that they have good reason: not only have orcas been known to prey on great whites, they seem to have a terrifying Hannibal Lecter-like penchant for eating the sharks' livers by making an incision near the pectoral fins with surgical-like precision and then sucking out the organ like foie gras.

Also known as killer whales, orcas can grow to lengths of more than nine metres,

making them bigger than all but the largest great whites.

In the study, the team used long-term electronic tagging devices to track the movements of great whites from 2007 to 2013 at a site in Southeast Farallon Island (SEFI) in the northeastern Pacific. Great whites go there to hunt juvenile elephant seals between April and May, and October and November. This area is also popular with visiting orcas who gather to hunt prey of their own in the autumn months. The team found that the great whites ate far fewer elephant seals in the years in which orcas were in the area at the same time.

Though no sharks were confirmed to be killed by orcas during the study, the team was able to confirm from their tracking data that the great whites quickly fled from areas patrolled by orcas and did not return for the remainder of the season.

ABOVE: "I ate his liver with some fava beans and a nice Chianti"

**NIGHTMARE SUFFERERS**

A team at the University of Turku discovered that the brain's right frontal cortex is particularly active in those who experience distressing nightmares. The finding could help us understand the neural basis of the emotional content of dreams, they say.

TALKATIVE PARENTS

Love a natter? You may be raising the next Einstein. Researchers at the University of York have found that pre-schoolers who are often spoken to by adults perform better in language, reasoning and numeracy tests.

Good month**Bad month****BEARDED MEN**

Bearded men can be dirtier than dogs, according to a Swiss study. Swabs were taken from the beards of 18 men aged 18 to 76, and the necks of 30 dogs. All the beards contained a high number of microbes, some of which are harmful to health. Just 23 of the dogs had significant numbers of microbes in their fur.

YOUNGSTERS

Fewer young people are earning more than their parents, a study at the University of Surrey has found. In 2005, more than half of 30-year-olds were on higher salaries than their dads; by 2017 that figure had fallen to less than a third.

**FAST TRACK TO A SIX-PACK**

Want six-pack abs but don't fancy bashing out hundreds of crunches every morning? Good news: a team at the University of Miami has devised a new method of removing stubborn fat from your muffin top. Dubbed 'abdominal etching', it uses precisely targeted liposuction to sculpt the abdominal fat to accentuate the patient's natural six-pack lines. The researchers trialled it on 26 men and 24 women who were in reasonable shape. The patients kept their chiselled torsos for up to six years.

**ANTHROPOLOGY**

Welcome to the family

A new species of tiny hominin has been discovered in the Philippines, adding a twist to our understanding of evolution

It could be time to update the family tree. A new species of human, called *Homo luzonensis*, was identified from fossilised remains found in Callao Cave on Luzon

Island by an international research team. The team found at least two adults and one juvenile, which are thought to be more than 50,000 years old. They would have existed at the same time as other human species, including Neanderthals, *Homo sapiens* (modern humans) and Denisovans. According to the study co-author, Prof Philip Piper

from the Australian National University (ANU), this discovery offers a major breakthrough in our understanding of how humans evolved in Southeast Asia.

"There are some really interesting features – for example, the teeth are really small," Piper said. "The size of the teeth generally, though not always, reflect the overall body-size of a mammal, so we think *H. luzonensis* was probably relatively small. Exactly how small we don't know yet. We would need to find some skeletal elements from which we could measure body-size more precisely."

Other excavations in the Philippines have uncovered the famous 1.1-metre-tall *H. floresiensis*, also known as 'the hobbit', which was found on the island of Flores. Additionally, 200,000-year-old stone tools have been identified on Sulawesi, suggesting that ancient humans may have occupied large swathes of the region.

Below:
Teeth and
toe bone
from *Homo
luzonensis*





LEFT: Wolf
pressing the
touchscreen to
deliver food

BELOW: Setting
up the test

ZOOLOGY

Wolves are better cooperators than dogs

Wolves are more charitable towards their pack members

In a touchscreen-based food task, wolves appeared to be more altruistic than dogs. This contrasts with the hypothesis that charitable behaviour appeared in dogs during the course of domestication, thanks to their relationship with humans. However, it confirms an alternative idea that ‘prosocial’ behaviour (helping, sharing or cooperating) is a trait derived from wolves, which are dogs’ ancestors.

In the study, which took place at the Wolf Science Center in Vienna, Austria, nine wolves and six dogs living in packs were trained to press their nose against a touchscreen to deliver food to a visible occupant in an adjacent enclosure.

Over the course of the study, the wolves chose to deliver more food to the adjacent enclosure when it contained a member of their own pack than when it was occupied by a non-member. This confirms previous research that relationships are an important part of prosociality in wolves. The dogs, on the other hand, delivered no more food to the adjacent enclosure when it was occupied by a member of their pack.

“This study shows that domestication did not necessarily make dogs more prosocial,” said study leader Rachel Dale. “Rather, it



seems that tolerance and generosity towards group members help to produce high levels of cooperation, as seen in wolves.” Cooperation is important for wolves, as they will work together when hunting, defending territory and looking after young. Pack dogs, on the other hand, are more solitary. Yet the researchers caution that we shouldn’t relate these findings to Fido. Pet dogs tend to show more prosocial behaviour, probably due to training and treats from their owners.



Prof Catharina Svanborg Immunologist

Horizons

Compound found in human breast milk has the potential to fight cancer

SWEDISH RESEARCHERS HAVE ISOLATED A MOLECULE FROM BREAST MILK WITH REMARKABLE TUMOUR-KILLING PROPERTIES. DUBBED 'HAMLET', SHORT FOR HUMAN ALPHA-LACTALBUMIN, THE SUBSTANCE IS UNDERGOING ITS FIRST HUMAN TRIALS

HOW DID YOU FIND HAMLET?

We were looking for natural antibacterial molecules in body fluids. We threw some lung cancer cells into the test tube with human milk and noticed that the tumour cells died. We had to repeat it a few times before we could believe our eyes.

WAS IT JUST RAW HUMAN MILK?

No, it wasn't actually. Human milk is a source for all sorts of molecules – obviously, it's a wonderful mix of molecular protection for babies. But we were using different fractions of it, because either you have antibodies, or you have small molecules, or you have sugars, or lipids. Depending on which fraction you're using, you can get very different results. It turned out that one of these fractions was causing the tumours to die, but not whole milk as it comes out of the breast. It has to be treated a little to bring out the HAMLET molecule.

HOW EXACTLY DOES IT WORK?

HAMLET has multiple effects on tumour cells. Cancer cells have a more primitive membrane than normal differentiated cells and it appears that HAMLET benefits from this. It inserts itself into the membrane and starts ion fluxes across it. Then, in the nucleus it binds to the very substance that the DNA and the proteins in the nucleus make. So, it's a bit like pouring cement on these cells. They just can't make new molecules and survive any longer.

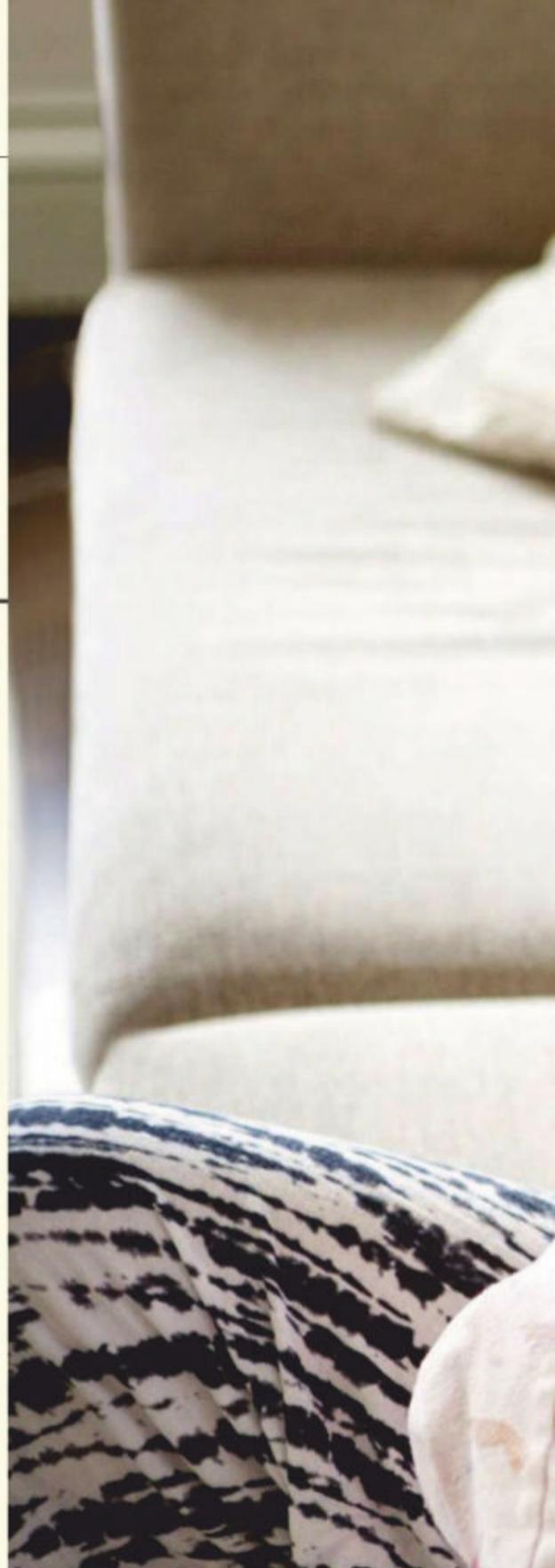
SO WHAT IS THIS COMPOUND'S PURPOSE IN THE BREAST MILK?

We've been trying to focus on the local effects in a baby's large intestine. There can be virus-infected cells in the intestine that need to be removed, instead of developing to become more mature, they could start to look like cancer cells. So, you could think of these HAMLET molecules as scavengers that remove cells like this that go the wrong way. There is also previous data on breastfeeding being protective for childhood lymphomas and certain kinds of intestinal cancers.

I GATHER YOU'VE ALREADY RUN A NUMBER OF IN-VITRO AND ANIMAL TRIALS?

Yes. The in-vitro trials were exhilarating because we used a range of different

GETTY IMAGES



The key to curing cancer may lie in human breast milk



"It's a bit like pouring cement on [cancer] cells. They just can't make new molecules and survive any longer"



cancer cell lines. Most of them are what we call carcinoma, so they are from tissues that develop into cancers. But we also looked at leukaemia and others. And to our great surprise most of these different cancer cells died in a similar way. We call it 'apoptosis' and it makes us think that we might be developing a molecule that presses some button in tumour cells. And so, the experiments in test tubes are very promising.

Of course, one cannot set up 40 different cancer models, but we have looked at quite a few. One is brain tumours where the model is that you remove the human tumour during surgery and you put it into an animal for it to develop. Then you treat the animal by local injection of a drug into its brain. This is the model that has been developed quite recently and it's very promising. The second one that we did was colon cancer and the third one

was bladder cancer in mice, where large tumours can develop quite rapidly. And if we inject HAMLET, or our now second-generation synthetic drug, into these mice, we can see a very potent, dose-dependent therapeutic effect.

CAN YOU USE A SYNTHETIC VERSION OF BREAST MILK?

Yes, we were fortunate in that the part of the HAMLET molecule that can be synthesised is the part responsible for the activity. This now being produced in state-of-the-art factories with sterility and all the other things that we need.

HAVE YOU CARRIED OUT ANY HUMAN TRIALS?

We're due to finish our first at the end of June and are looking forward to getting the data. It's a double-blind placebo control trial, so we have no idea who is getting the drug and who isn't. The patients have

what's called superficial bladder cancer, and, in part, we selected this variety because we have previously performed an academic human study in bladder cancer and have seen some positive effects, so it was considered that the most realistic indication for this type of trial. We're already very happy, because there is no evidence of severe side effects, which is quite a relief. And then, of course, we'll have to wait and see if the patients really benefit from this treatment.

PROF CATHARINA SVANBORG

Catharina is a professor of immunology at Lund University in Sweden. **Interview by BBC Science Focus commissioning editor Jason Goodyer.**

Primer

Death redefined?

BRAIN DEATH ISN'T THE END... AT LEAST, NOT FOR THE SLAUGHTERED PIGS WHO HAD THEIR BRAINS REVIVED, THANKS A NEW TECHNIQUE

SOMEONE'S BROUGHT A PIG BACK TO LIFE?

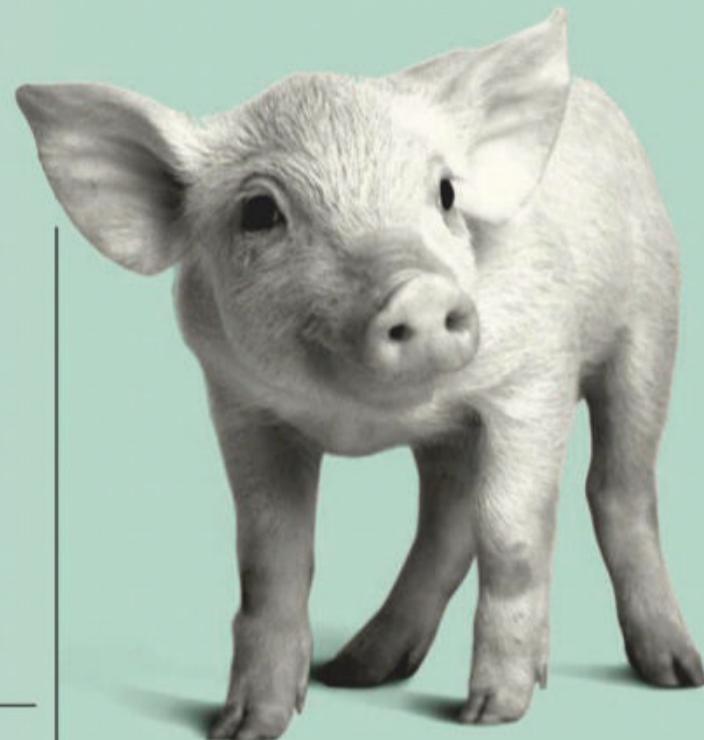
Not exactly. Neuroscientists at Yale University, led by Prof Nenad Sestan, temporarily restored some cellular function in pigs' brains approximately four hours after the pigs had been slaughtered. It's important to note, however, that the brains had been removed from the pigs' heads.

SO THE PIGS AREN'T ALIVE?

No. But for a while their brains weren't dead either... well, not in the technical sense. Medically speaking, and in most countries legally, a sentient being is declared dead when their brain function has ceased. Without brain function, a person, or in this case a pig, is unable to breathe or pump blood around their body on their own, and without a supply of blood and oxygen their brain cannot regain consciousness. But by artificially pumping a blood substitute around the disembodied pig brains, Sestan's team managed to keep the cells in the revived organs alive for 36 hours.

HOW DID THEY DO IT?

According to their research paper published in the journal *Nature*, the Yale scientists hooked the dead pigs' brains up to a system called BrainEx. BrainEx has been specially developed to circulate a solution containing



X

"By artificially pumping a blood substitute around the disembodied pig brains, Sestan's team managed to keep the cells in the revived organs alive for 36 hours"

oxygen and nutrients around the disembodied organs. Once the solution was circulating, the team monitored the brain cells and saw that they were absorbing oxygen from the solution and releasing carbon dioxide – processes that are both indicative of normal metabolic function. The revived brain cells also showed decreased rates of decomposition

compared to those in control brains that weren't connected to the BrainEx system.

Perhaps most astonishing of all, however, was that Sestan's team not only saw signs of an immune response in the revived brain cells (as if they were attempting to repair the damage that had been caused by their deaths) but also that the neurons in the revived brains were still capable of signal transfer.

HOW DID THE PIGS FEEL ABOUT ALL THIS?

They didn't. Although the revived brains were able to transfer signals, the solution being pumped around them carried chemicals to prevent widespread coordinated synaptic activity from being restored. In other words, the Yale scientists took steps to ensure the pigs' brains wouldn't regain consciousness, in order to prevent them from experiencing pain. But even if the brains did regain some measure of consciousness, Sestan's team were on hand with anaesthetics, just in case.

WHAT DOES ALL THIS MEAN?

It's difficult to say with any degree of certainty. Although the technique shows that cell function can be restored in brains post mortem, currently it only works on brains that have been removed from their owners' skulls. It does, however, provide a new avenue for studying brain function and may lead to new treatments for reducing brain injury as a result of depleted or disrupted blood flow, the kind caused by heart attacks or strokes.

Furthermore, if the technique can be successfully applied to human brains (which the Yale team points out is a long way off), it's feasible that it could be used to test drugs that could not be ethically administered to living subjects. There are wider implications to consider, though, the main one being what this means for the current medical and legal definitions of death.



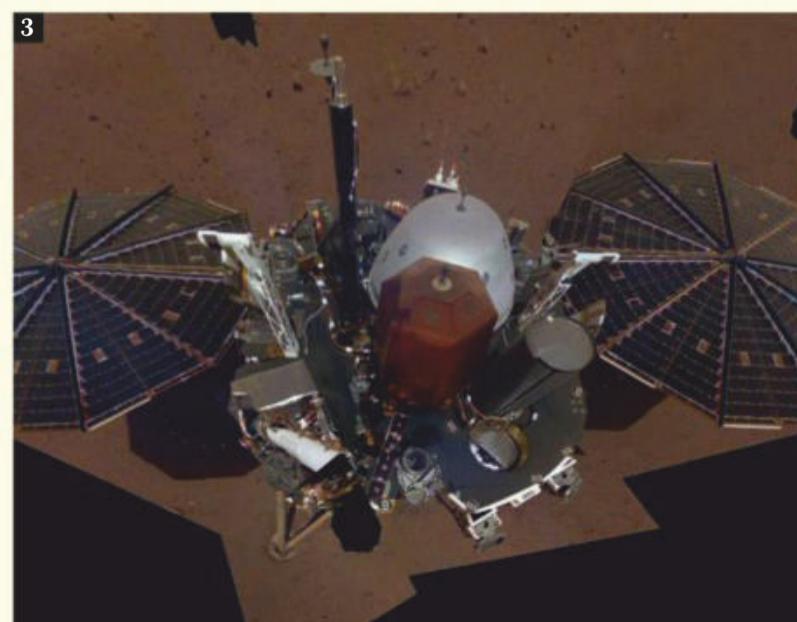
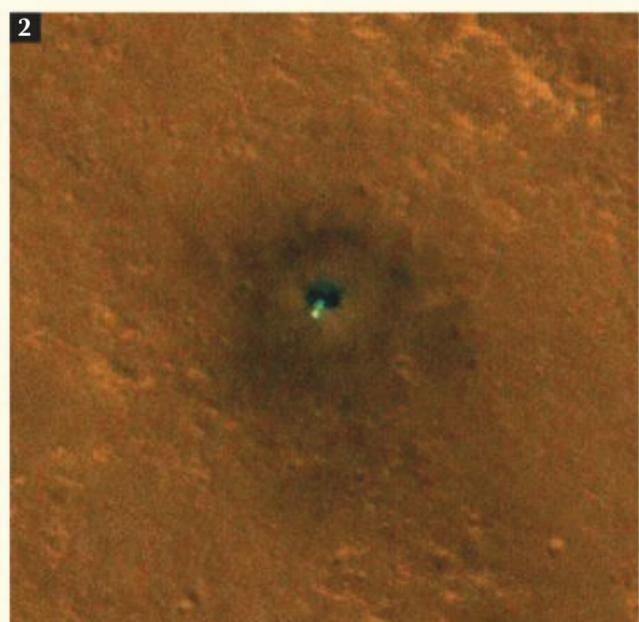
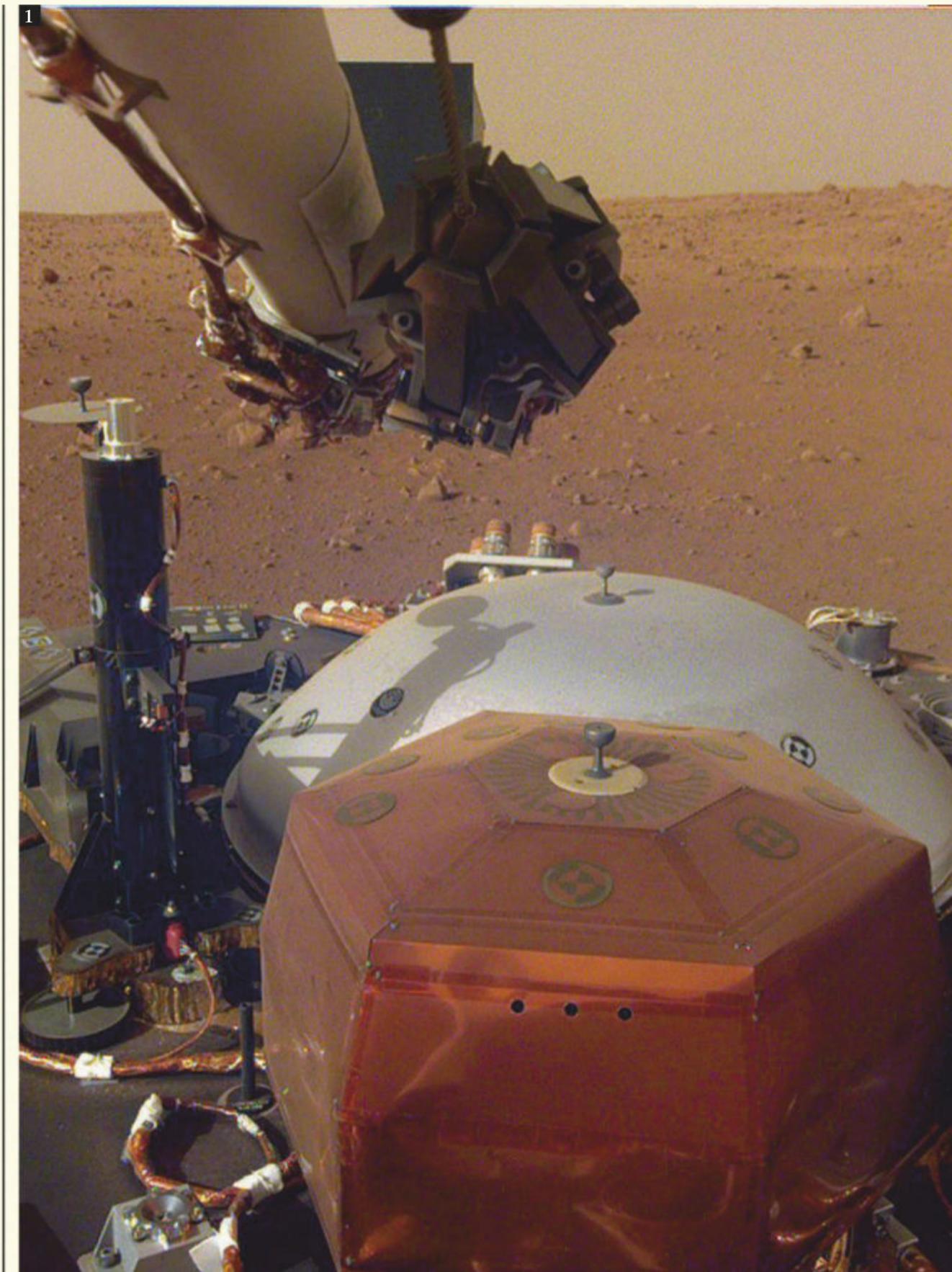
SPACE

NASA'S INSIGHT LANDER DETECTS FIRST 'MARSQUAKE'

On 6 April, NASA's InSight lander detected a faint signal that was thought to have been caused by the movement of a crack deep within the Red Planet, or perhaps by a meteorite impact. It took place on the 128th Martian day of the mission, and was the first seismic signal detected on a planet other than Earth. The signal was detected by SEIS, the lander's seismometer that was designed and built in a collaboration between French and British researchers.

"InSight's first readings carry on the science that began with the Apollo missions," said InSight's principal investigator Bruce Banerdt of NASA's Jet Propulsion Laboratory in Pasadena, California. "We've been collecting background noise up until now, but this first event officially kicks off a new field: Martian seismology."

The lander touched down on the surface of Mars in November and will study the planet's interior structure with the hope of answering key questions about the early formation of rocky planets in the Solar System for the next two years.



1. The polyhedron structure houses SEIS – the seismometer that measures the internal activity of Mars. The dome was placed over SEIS to protect it from the Martian elements.

2. This image of NASA's InSight lander was taken by the HiRISE camera aboard NASA's Mars Reconnaissance Orbiter on 4 February.

3. This is NASA InSight's first full selfie taken on Mars on 6 December 2018. It was made by stitching together 11 separate images taken by its Instrument Deployment Camera located on the 'elbow' of its robotic arm.

Tall stories

Exploring the skylines of tomorrow

DATA VISUALISATION: JAMES ROUND

Over the last 200 years or so, following the Industrial Revolution, the urban population has been growing. People have been flocking to cities, lured by promises of better jobs, more money, and improved quality of life. Experts estimate that this trend will continue, and all these people will need places to live, leading to a larger number of tall buildings and megacities.

What makes a skyscraper?

Building heights are measured by the Council on Tall Buildings and Urban Habitat. In ranking the world's tallest buildings, structures are measured to their 'architectural top', which includes spires, but excludes things like flagpoles. If a building is over 300m tall, it's defined as being 'supertall'. Over 600m tall and it's classed as 'megatall'. More ambiguity exists over the wider definition of a 'tall' building, and although often subjective, this is considered against the following:

HEIGHT RELATIVE TO CONTEXT



A 10+ storey building might not be considered tall in a city like New York, but in a town or suburb it may tower above its surrounding neighbours.

HEIGHT RELATIVE TO PROPORTION



Some buildings may not be particularly high, but are slender enough to give that impression. Conversely, some buildings may be relatively high but have huge footprints, and therefore do not appear to be tall.

Key

The visual below charts the construction of recent and future tall buildings, organised by continent and size.

Spike height refers to the number of buildings in a category, while colour refers to building height.

The definition of smaller tall buildings can be subjective, but for simplicity the following criteria were used:

Above 50m	Above 100m
Tall building	Skyscraper
Above 300m	Above 600m
Supertall building	Megatall building

Past

1 Construction finished by 2000

Present

2 Construction finished by 2020

Future

3 Proposed or currently under construction with a completion date later than 2020

Annotations on main visualisation show what the continent's highest building will be in 2020

Numbers listed under buildings refer to height in metres, number of floors and year built. For example, 541m / 94 floors / built in 2014

One World Trade Center

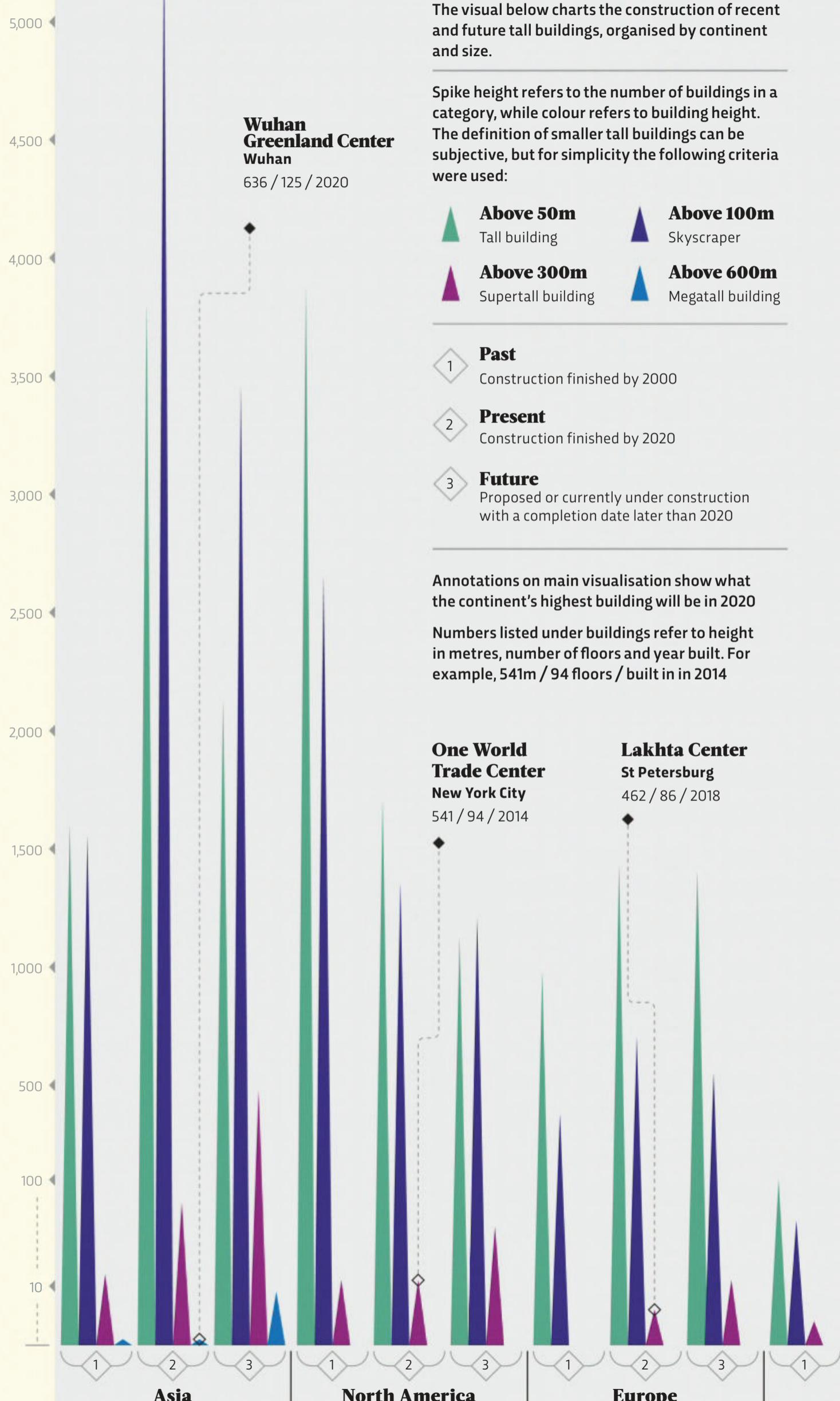
New York City

541 / 94 / 2014

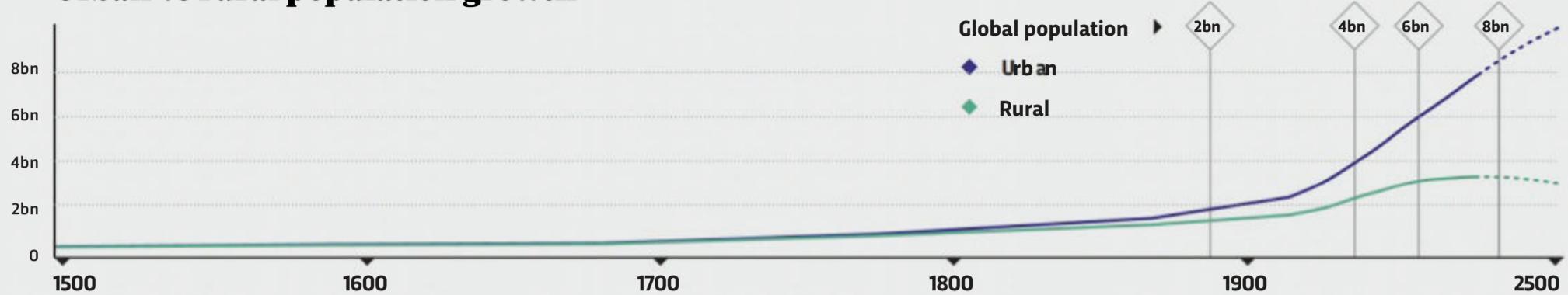
Lakhta Center

St Petersburg

462 / 86 / 2018

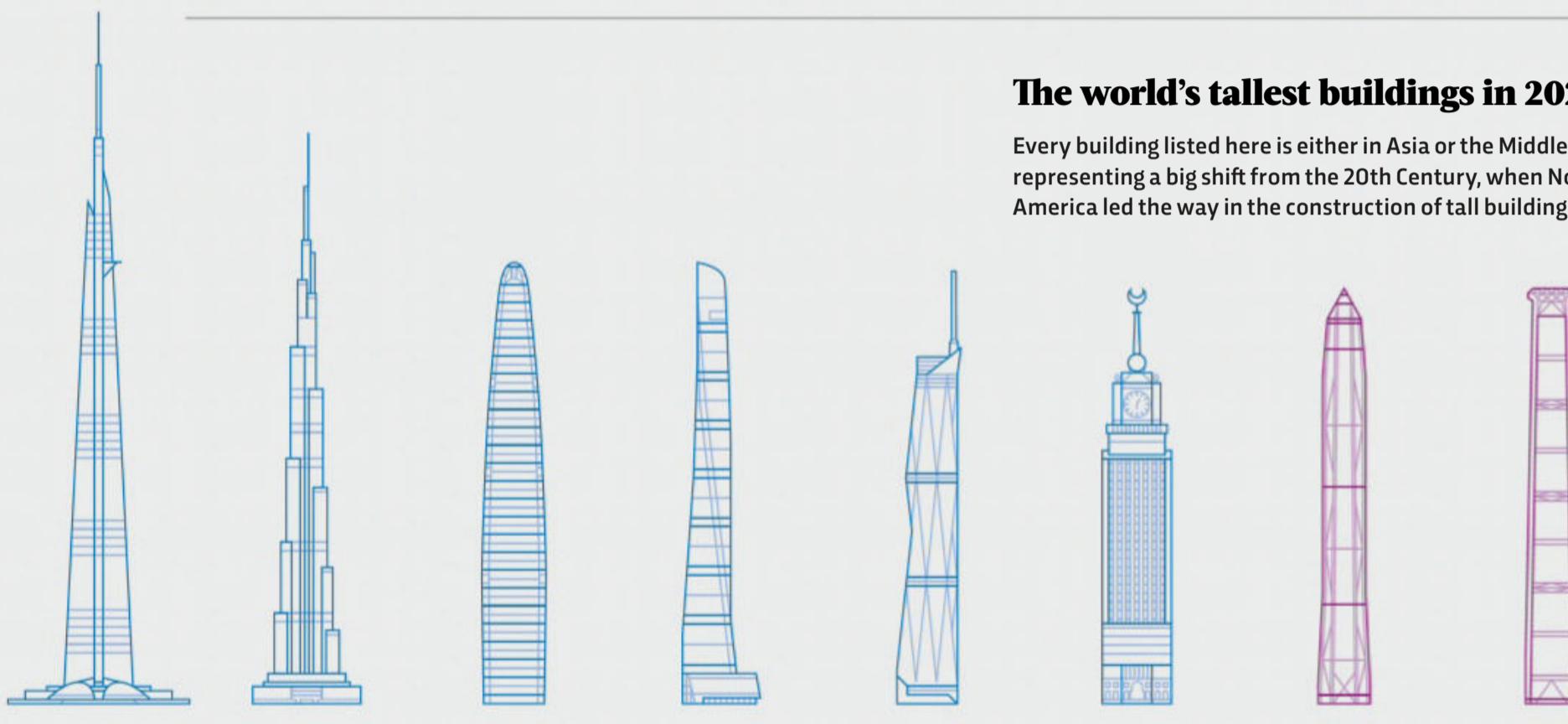


Urban vs rural population growth



The world's tallest buildings in 2020

Every building listed here is either in Asia or the Middle East, representing a big shift from the 20th Century, when North America led the way in the construction of tall buildings.



1 Jeddah Tower Jeddah 1,000 / 167 / 2020	2 Burj Khalifa Dubai 828 / 163 / 2010	3 Wuhan Greenland Center Wuhan 636 / 125 / 2018	4 Shanghai Tower Shanghai 632 / 128 / 2015	5 Merdeka PNB118 Kuala Lumpur 630 / 118 / 2020	6 Makkah Royal Clock Tower Mecca 601 / 120 / 2012	7 Ping An Finance Center Shenzhen 599 / 115 / 2017	8 Goldin Finance 117 Tianjin 597 / 128 / 2018
---	--	--	---	---	--	---	--

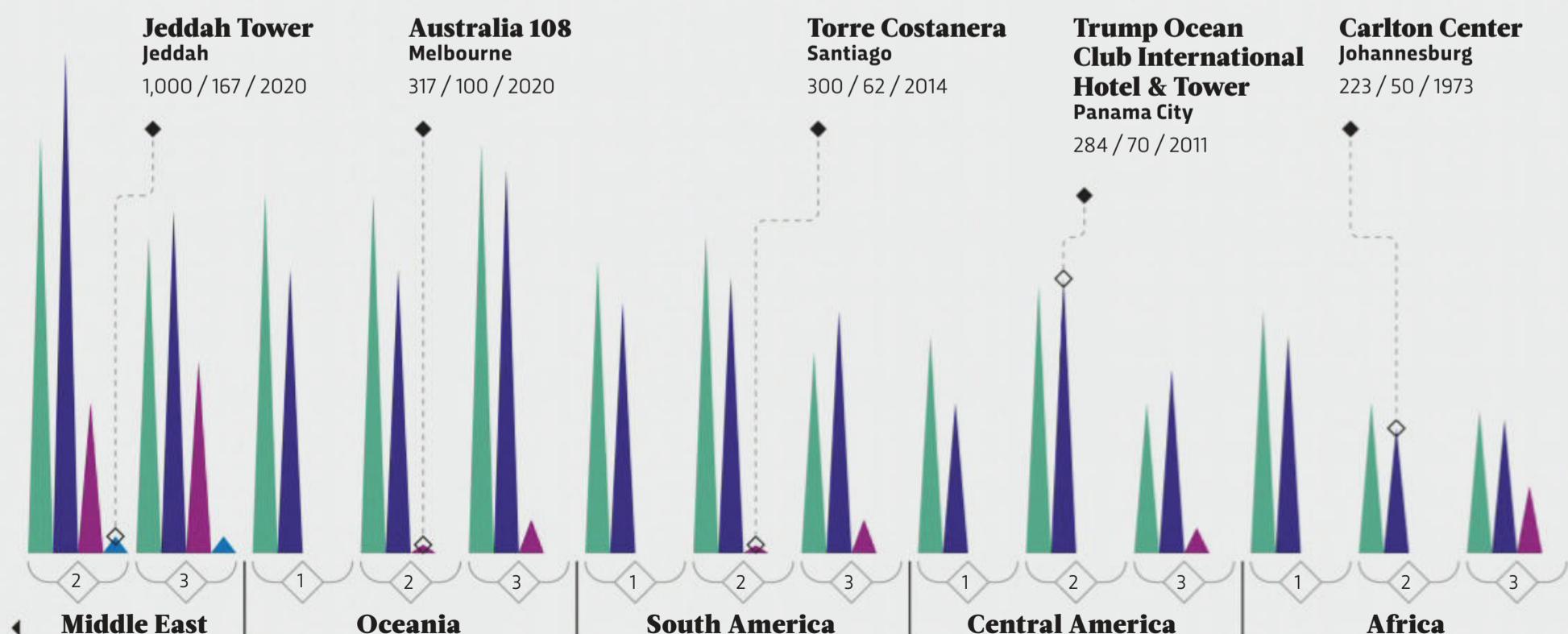
Jeddah Tower
Jeddah
1,000 / 167 / 2020

Australia 108
Melbourne
317 / 100 / 2020

Torre Costanera
Santiago
300 / 62 / 2014

Trump Ocean Club International Hotel & Tower
Panama City
284 / 70 / 2011

Carlton Center
Johannesburg
223 / 50 / 1973



PC Specialist recommends Windows



Windows 10

PROTEUS VI RTX

15.6" Matte Full HD IPS Screen

Intel® Core™ i7-8750H

16GB Kingston DDR4 2133MHz

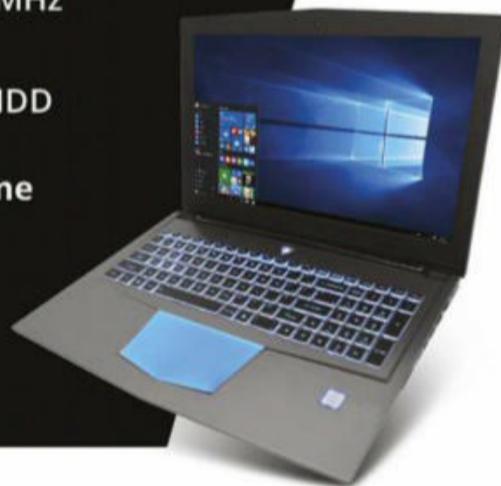
8GB GeForce RTX 2070

1TB SEAGATE 7mm SATA HDD
(7,200)

Genuine Windows 10 Home

This spec from

£1,349.99



DEFIANCE V RTX

17.3" Matte Full HD 144Hz Screen

Intel® Core™ i7-8750H

16GB Corsair 2133MHz

8GB GeForce RTX 2070 Max-Q

1TB SEAGATE 7mm SATA HDD
(7,200)

Genuine Windows 10 Home

This spec from

£1,449.99



**GET A FURTHER £15 OFF WITH
THIS EXCLUSIVE VOUCHER CODE:**

BBF19

0333 011 7000

Some features require Windows 10. Update available through Windows Store. Internet access required; fees may apply.
Microsoft, and Windows are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

* Prices are including VAT and are correct at the time of printing, but subject to change.

/PCSPECIALIST

@PCSPECIALIST



PC SPECIALIST



CUSTOM GAMING DESKTOPS & LAPTOPS

ORDER ONLINE NOW AT

WWW.PCSPECIALIST.CO.UK

SCIENCE BEHIND THE HEADLINES

REVIEW

1. REVIEW

Notre-Dame

2. ANALYSIS

Chinese research

3. COMMENT

Biohacking



1

REVIEW

NOTRE-DAME: HOW FAITHFULLY CAN WE REBUILD THE CATHEDRAL WITH MODERN TECH?

French President Emmanuel Macron has promised to rebuild the cathedral in the aftermath of the fire. How will it be done?

On Monday 15 April, the famous Parisian cathedral Notre-Dame was struck by tragedy when an enormous fire broke out. The blaze was discovered at 6:43pm local time, and firefighters tackled the flames through the night, finally extinguishing it by 10am the following morning. At the time of writing, the exact cause of the fire is not yet known, though investigators have suggested that it might have been an electrical short circuit.

World leaders, billionaires and various companies pledged money and support for the restoration, and President Emmanuel Macron set a target for the building to be completed within five years, in time



Laser scanner

Andrew Tallon used the Leica ScanStation C10 to capture Notre-Dame. It fires laser pulses at a rapidly spinning mirror as the head slowly rotates, scanning up to 50,000 points per second and filming the surroundings with its integrated video camera. This allowed Tallon to scan the entire cathedral in five days.



GETTY IMAGES, VASSAR COLLEGE/COLUMBIA UNIVERSITY, LEICA

WANT MORE?

 For more stories like this, visit our website at sciencefocus.com/realitycheck

for the 2024 Summer Olympics in Paris. Experts have called for a longer deadline.

Unlike many other buildings under restoration, the original construction of Notre-Dame is known in exquisite detail, thanks to the work of art historian Andrew Tallon. Tallon, who died in November 2018, catalogued the entire building using the technique of laser scanning.

What is laser scanning?

Laser scanning is a technique that maps buildings and objects in 3D. James Miller, who chairs the Conservation Accredited Register of Engineers in the UK and Ireland, explains: "What it means is that you've effectively captured the whole building or structure at its surface. You define precisely where it was. That's of immense value." According to Tallon, the scan is accurate to within five millimetres.

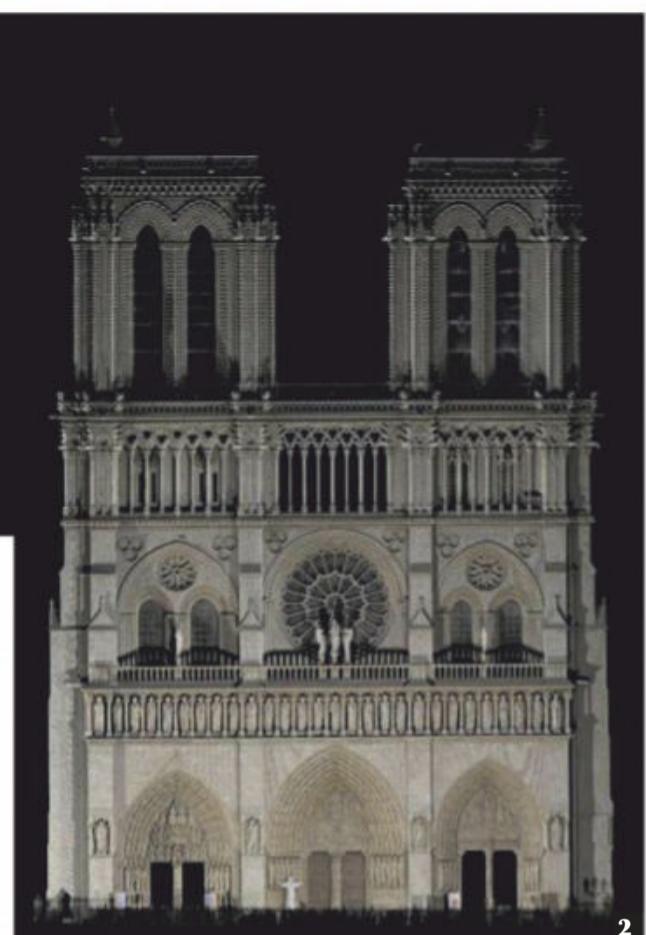
How is laser scanning carried out?

The laser scanner has a spinning head on a tripod, which is placed at a series of points inside and outside the building. As the head spins, it fires a low-intensity laser and captures it on return. "This beam bounces off the surfaces that it meets and the location of each bounce is recorded," Miller says.

The scanner measures the time for the pulse of light to return after it has reflected from the surface. The beam's journey time tells the scanner how far away the surface is. "You might, in some way, liken it to a form of radar," says Miller. "But it's a much more sophisticated thing in that it's locating whole surfaces and large numbers of

1 Fire-fighters race to extinguish the flames engulfing Notre-Dame

2 One of Andrew Tallon's detailed 3D scans of Notre-Dame



points in a very short period of time. A laser scanner can record up to a million points every second, forming a precise image of the surfaces. The resulting image is a constellation of dots showing the shadow of the building. It's a tool that defines geometry. It defines where each stone is – the joints in the stones, virtually," explains Miller.

The reproduction of Notre-Dame is comprised of scans from 50 different angles inside and outside the building, making up a total of over one billion data points. To make sense of the data, Tallon combined the laser scans with spherical panorama photographs taken from the same spot to capture the colours. When the photographs were mapped onto the scanned dots, this produced the ghostly form of the cathedral.

How extensive was the damage to Notre-Dame?

The wooden interior of the cathedral and its spire were both destroyed by the fire. The 13th-Century glass of the three famous rose windows survived, though they sustained some damage.

According to Laurent Nuñez, France's deputy interior minister, the main structure of the cathedral is in generally good condition despite the fire, thanks to the firefighters saving the building within the last crucial half-hour before it would have been destroyed. ➤

● Many of the cathedral's priceless artefacts were saved, thanks to priests and churchgoers forming a human chain to remove them quickly. Jean-Marc Fournier, chaplain of the Paris fire brigade, managed to save the Crown of Thorns, said to have been worn by Jesus during the crucifixion.

Will Notre-Dame be rebuilt exactly the same?

One distinct difference in the rebuilt Notre-Dame will be its spire. Édouard Philippe, France's prime minister, has announced an international competition to design the new spire, saying that they must decide whether it should be rebuilt as it was, or "adapted to the techniques and issues of our era".

Another factor to consider is whether to recreate the original building's flaws. Tallon's scans revealed that the original builders between the 12th and 14th Centuries constructed the building around existing structures, resulting in uneven columns and aisles, and Tallon likened the western end to "a total train wreck".

Miller says that the reconstructed building doesn't have to have the same inconsistencies. "At Notre-Dame, we have a structure that, like many buildings the world over, it's breathed, it's moved, it's settled, it's pushed a bit on the corners. Those imprecise, odd corners – what are we going to do about them?" The answer, he says, is to match the new building work with what remains.

"Rather like filling in a big gap where there's a jigsaw already completed round the edges, we've got to decide what to do in the middle. If it used to be a bit crooked in the middle, but the middle is gone, we don't have to make it crooked. We can build it a little bit more perfect," he explains. "What you mustn't do is, when you get to the edges, misalign at that point."

Could the original building material be reused?

As much of the original building material should be used as possible. However, that

might not be feasible. "I regret to say that, if we've had stonework falling, particularly from the ribs of the building, it will be seriously damaged," says Miller.

The fall itself isn't necessarily the source of damage to the stonework. According to Miller, a big problem with fire is the firefighting itself. Cold water hitting hot stone causes thermal shock, which is the result of a dramatic temperature change in an object. When cold water suddenly cools a fire-heated stone, the stone contracts rapidly. If it doesn't cool evenly, then it won't contract evenly, and tiny fissures can form. These will rapidly spread across the whole object, which will then split apart.

Thermal shock can happen when a hot object is rapidly cooled, or when a cold one is warmed. That's why an ice cube cracks when dropped in warm water, or a hot frying pan warps when doused in cold water.

How will the building material be replaced?

Good conservation practice dictates that the new building material should be as similar as possible to the original. "What they will be looking to do is source stone that matches, to look at the quarrying, to look at the type that was used," says Miller.

The wooden structure, originally made from 1,300 12th-Century oak trees, could be rebuilt with donated wood. Over 100 British stately homes, including Scone Palace in Perth and Belvoir Castle in Lincolnshire, have offered to contribute oak trees.

by SARA RIGBY

Sara is the online assistant for BBC Science Focus. She has an MPhys in mathematical physics.

DISCOVER MORE



Visit the BBC's Reality Check website at bit.ly/reality_check or follow them on Twitter @BBCRealityCheck

GETTY IMAGES X3, OHIO UNIVERSITY, ALAMY

2 ANALYSIS

From rhesus monkeys with human intelligence genes to CRISPR-edited human babies, has Chinese research gone too far?

PRIMATE RESEARCH: HAS IT CROSSED AN ETHICAL LINE?



A macaque sits in the snow in a Chinese Zoo

When it comes to gene editing, how far is too far? Chinese scientists have been pushing the boundaries, most recently by creating rhesus monkeys with a human brain gene linked to intelligence. The experiments were widely criticised, with anthropologist Barbara J King describing them as “an ethical nightmare”.

This isn’t the first time that China’s gene-editing research has drawn criticism. In November 2018, He Jiankui of the Southern University of

Science and Technology in Shenzhen announced the birth of two human babies altered with the gene-editing tool CRISPR to give them a natural resistance to HIV. In response to the research, just three months later, the Chinese government announced tighter regulations on gene editing in human subjects.

In January 2019, reports emerged that macaques had been cloned from another macaque, which lacked a gene controlling its sleep-wake cycle. With this gene disabled, they were predisposed to psychiatric ➤

NEED TO KNOW
Timeline of
gene-editing experiments

1981

FIRST TRANSGENIC ANIMAL BORN
A mouse with an implanted rabbit gene was created at Ohio University.



1996

DOLLY THE SHEEP CLONED
Dolly, the first ever cloned mammal, was born at the Roslin Institute, Edinburgh.



2003

HUMAN GENOME MAPPED
After 13 years of study, the Human Genome Project was completed.



2012

CRISPR TECHNOLOGY DEVELOPED
The gene-editing tool CRISPR was developed by Jennifer Doudna and Emanuelle Charpentier (left).



“I think if those standards are being side-stepped, then that’s unethical”

• disorders, and they displayed anxiety and ‘schizophrenia-like’ behaviours. The research was carried out at Shanghai’s Institute of Neuroscience.

Next came rhesus monkeys carrying a human gene for brain development, created by researchers at Kunming Institute of Zoology. These monkeys developed a better short-term memory than their non-altered peers, and also showed a slower, human-like brain development.

Research on primates is highly regulated in the UK and Europe, and experiments on them must meet stringent welfare standards. “I think if those standards are being side-stepped, then that’s unethical,” says Prof Julian Savulescu, who holds the Uehiro Chair in Practical Ethics at the University of Oxford.

It is not the experiments themselves that could be considered unethical, Savulescu explains, but the way the subjects are treated. “Is it unethical to make an animal more intelligent? Not in itself,” he says. “Already mice have been genetically modified to have better memories. It’s a question of what those modifications do to the animal’s wellbeing and how that animal is treated.”

An animal with a higher mental capacity also has a greater capacity to suffer if its needs aren’t met. “As you start to improve or enhance the intelligence or empathy or capacity for social relationships, or any property, then there’s a corresponding obligation to treat the animal in a way that those capacities are developed and also that they are not associated with suffering for the animal,” explains Savulescu.

How an animal should be treated is not an easy question, especially when it comes to something new, such as monkeys with human-ish brains. “One of the challenges is deciding: what are the properties that give an animal a moral status equivalent to a human?” says Savulescu. “Then there’s the challenge of testing whether a new kind of animal, whether it’s been genetically modified or whether it’s a chimera [an organism containing multiple sets of DNA], actually has those properties.”

But what happens if, further down the line, unethical primate experimentation leads to a major breakthrough?



“The real problem is going to come if, on the back of this, they develop actual medicines or procedures that really do work and treat serious human diseases. Are we then going to turn our backs on those? I don’t think so, at that stage. It really is important to stop this research early on,” explains Savulescu. “It’s one thing not to publish the research, but I think that the pressure to use the results in the future will be irresistible.”

Science journals and researchers will need to work together to reject this direction of experimentation. “It’s difficult to enforce laws. You need social pressure through norms,” Savulescu says. “If it doesn’t conform to the right standards, it shouldn’t be published and it shouldn’t be used.”

One of the macaques that has been cloned to be predisposed to psychiatric disorders

by SARA RIGBY

Sara is the online assistant for BBC Science Focus.
She has an MPhys in mathematical physics.

“**The real problem is going to come if, on the back of this, they develop actual medicines or procedures that really do work**”

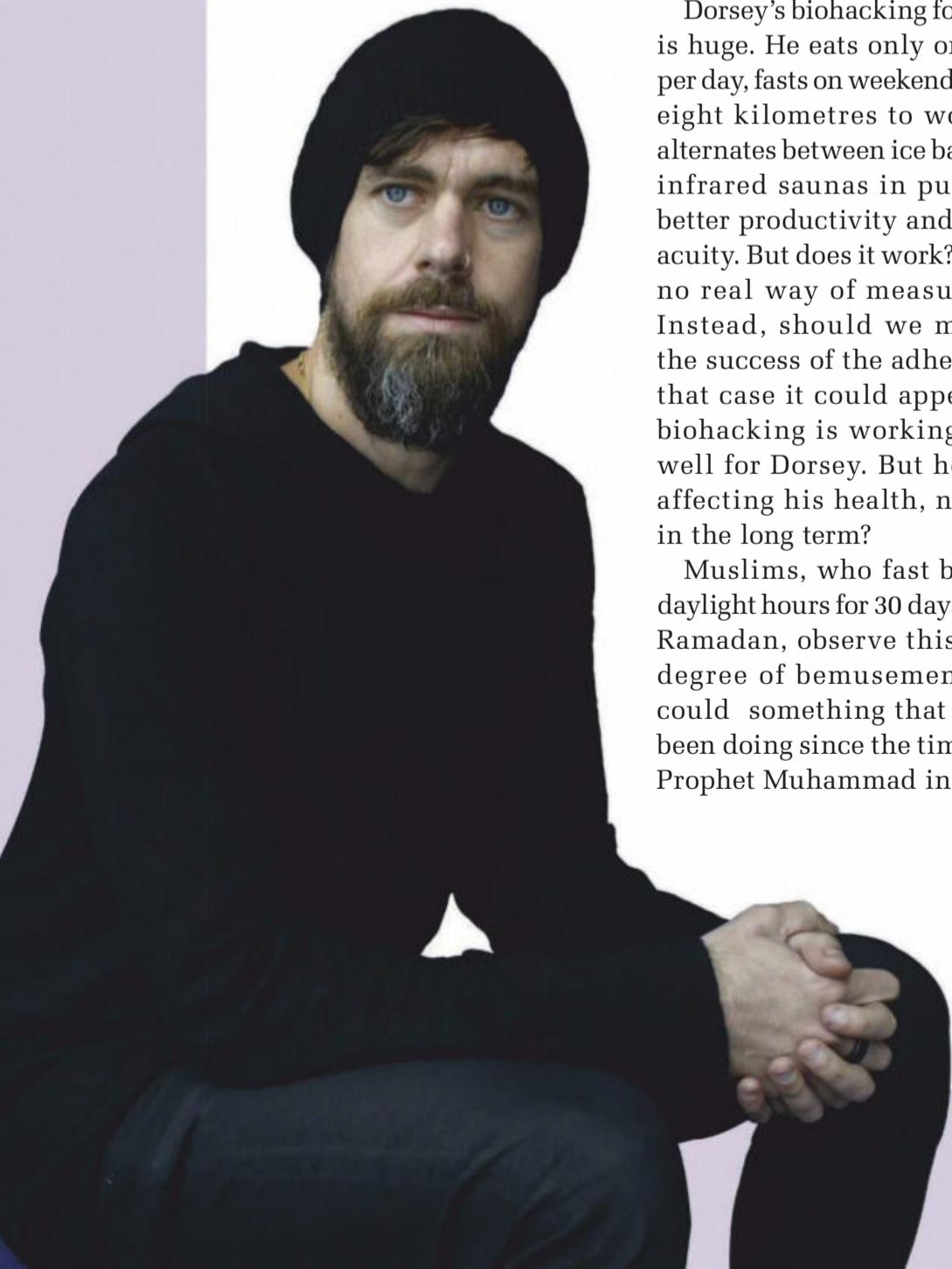
3

ANALYSIS

BIOHACKING: THE KEY TO OPTIMAL PERFORMANCE?

Are Silicon Valley CEOs who 'hack' their lifestyle cracking the code of productivity, or simply risking their health?

Jack Dorsey, Twitter CEO and keen proponent of 'biohacking'



Who doesn't want to increase their productivity, keep sharp and deliver their best work without suffering any energy dips?

Those Silicon Valley types are on the trail of cracking the code. The likes of Twitter CEO Jack Dorsey are trying biohacking, by living their lives through a strict structure of routines and intermittent fasting.

Biohacking is quite literally 'hacking' your lifestyle in a bid to enhance mental and physical performance. Techniques include strict diets (including meal-replacement shakes), unusual working regimes, meditation, exercise, oral supplements, ice baths and infrared saunas. In the extreme, biohackers even get implants. Companies that advocate

this claim they do so in the name of bionic human augmentation.

Dorsey's biohacking following is huge. He eats only one meal per day, fasts on weekends, walks eight kilometres to work and alternates between ice baths and infrared saunas in pursuit of better productivity and mental acuity. But does it work? There's no real way of measuring it. Instead, should we measure the success of the adherent? In that case it could appear that biohacking is working pretty well for Dorsey. But how is it affecting his health, now and in the long term?

Muslims, who fast between daylight hours for 30 days during Ramadan, observe this with a degree of bemusement. How could something that they've been doing since the time of the Prophet Muhammad in the 7th

Century, now be a Silicon Valley 'thing'? Yet it's not just Silicon Valley techies who are getting in on the fasting. Devotees of another kind of religion, the followers of lifestyle gurus, are also restricting their food.

Facebook biohacking group members support each other to go another day without food, and share their ketone levels. In medicine, we use this as a measure of the body's starvation levels. Many intermittent fasters describe feeling euphoric after two days of limited food intake, and claim their productivity improves. That sense of elation for having made it two days without food has also been described by anorexia sufferers. Similarly, Dorsey describes how ice baths give him a sense of euphoria, something open water swimmers have experienced for years.

Broken down, nothing is new. Is this really the key to improved productivity or is it actually repetitive, obsessive, ritualist behaviour and an eating disorder that requires support? That's hard to answer, since productivity is difficult to quantify, and eating disorders cannot be diagnosed remotely.

One measurable parameter, however, is the number of people flocking to imitate practices of successful high-profile biohackers. Global conferences with renowned biohackers like Dave Asprey, the creator of the Bulletproof Coffee, claim they will 'wake up your untold potential' and help you to become 'an upgraded human'. When most of us are juggling stressful lives, of course this is going to appeal.

If it works and delivers the elixir to an improved, more productive lifestyle, then of course it's worth a look. But there's very little science and research associated with much that these internationally-renowned biohackers preach. If it sounds too good to be true, then it probably is.

by DR SALEYHA AHSAN,
Saleyha is an A&E doctor in Bangor, North Wales. She also presents BBC programmes like Trust Me, I'm A Doctor and Panorama.

BBC
Science Focus MAGAZINE
SUBSCRIPTION ORDER FORM

Please complete the order form and send to:

FREEPOST IMMEDIATE MEDIA (please write in capitals)

UK DIRECT DEBIT

Yes, I would like to subscribe to/renew *BBC Science Focus Magazine*, paying £19.99 every six issues, plus receive a copy of *Our Planet*.

YOUR DETAILS (ESSENTIAL)**

Title _____ Forename _____

Surname _____

Address _____

Postcode _____

Home phone no. _____

Mobile phone no.** _____

Email** _____

I wish to purchase a gift subscription

(please supply gift recipient's name and address on a separate sheet)

Instructions to your bank or building society
to pay by Direct Debit



To: the Manager (bank/building society)

Address _____

Postcode _____

Name(s) of account holder(s)

Bank/building society account number

Branch sort code

Reference number (internal use only)

Originator's identification number

7 1 0 6 4 4

Please pay Immediate Media Co Bristol Ltd debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Immediate Media Co Bristol Ltd and, if so, details will be passed electronically to my bank/building society.

Signature _____

Date / /

Banks and building societies may not accept Direct Debit mandates from some types of account

KEEP IN TOUCH

***BBC Science Focus Magazine* (published by Immediate Media Company Limited) would like to send you updates, special offers and promotions by email. You can unsubscribe at any time. **Please tick here if you would like to receive these**

We would also like to keep in touch by post and telephone about other relevant offers and promotions from Immediate Media. If you do not wish to be contacted this way please tick here post phone For more information about how to change the way we contact you, and how we hold your personal information, please see our privacy policy which can be viewed online at immediate.co.uk/privacy-policy

OTHER PAYMENT METHODS

- UK cheque/credit/debit card** – £52.40 for 14 issues, **saving 25%** plus receive a copy of *Our Planet*
- Europe inc Eire** – £73.35 for 14 issues
- Rest of world** – £74.75 for 14 issues
- I enclose a cheque made payable to Immediate Media Co Ltd for £ _____

Visa Mastercard Maestro

Issue no. Valid from Expiry date

Signature _____ Date _____

If credit card address is different, please use the order hotline 03330 162 113

OVERSEAS Please complete the order form and send to: *BBC Science Focus Magazine*, PO Box 3320, 3 Queensbridge, Northampton, NN4 7BF

*Offer ends 19 June 2019. The book is available to UK residents only and 30% saving is only available to UK residents paying by Direct Debit. Stock is subject to availability and *BBC Science Focus Magazine* reserves the right to substitute the gift for another. Gifts in stock will be sent separately within 28 days. Your subscription will start with the next available issue.



You may photocopy this form



£4.99
you pay
£3.33*

SAVE OVER 30%

AND GET A COPY OF *OUR PLANET*
WHEN YOU SUBSCRIBE TO *BBC SCIENCE FOCUS MAGAZINE**

Receive *OUR PLANET*, the striking photographic
companion to the NETFLIX documentary series

Spread the cost and pay just £19.99 every 6 issues
by Direct Debit, saving over 30%!*

Receive every issue delivered direct to your
door with FREE UK delivery

Online
[buysubscriptions.
com/SFP336](http://buysubscriptions.com/SFP336)

Phone
03330 162 113+
(please quote SFP336)

Post
FREEPOST
IMMEDIATE MEDIA
(please write in capitals)





THE SHARPEST TOOLS

TOOL USE IS NOT RESTRICTED TO HUMANS AND IS FOUND THROUGHOUT NATURE. HERE ARE SOME OF EARTH'S MOST INNOVATIVE ANIMALS

Words: HAYLEY BENNETT

BRIGHT AS RAIN

← BORNEAN ORANGUTAN

When it rains, we humans get out our umbrellas. When it rains at the Camp Leakey research facility in Borneo, the orangutans make their own. Photographer Thomas Marent was observing this mother and baby when the skies opened. While taking out his umbrella to protect his camera, he saw the mother start to collect leaves from the tree. "She formed a kind of hat or shelter," he says. "She was sitting this way for about 20 minutes." Wild orangutans have also been observed using sticks to get seeds out of fruit and for measuring the depth of water to establish whether it's safe to cross. However, researchers think we probably see even more innovative behaviours in captive orangutans, because in the wild they learn from their parents and rarely explore or come across new problems to solve. Orangutans at San Diego Zoo famously escaped from their enclosure nine times, once using a crowbar. If that's anything to go by, they're truly some of the smartest – and sneakiest – of the primates.

GRAB AND SMASH

ORANGE-DOTTED TUSKFISH ↓

Fish aren't generally known for their intellect. But the surprising behaviour of 'Percy', an orange-dotted tuskfish living in Australia's Great Barrier Reef (and star of 2017's *Blue Planet II*), has got scientists thinking. While not sophisticated enough to use a stone as a hammer, like some monkeys do, he did hold clams in his mouth and carried them to a hard coral. He then used the coral as an anvil to smash open the shellfish, releasing the food within. Experts are still debating whether or not this constitutes real tool use. Is an anvil a tool, or does a tool have to be a separate object that's held and manipulated, like the monkey's hammer? Either way, Percy has demonstrated some impressive cognitive abilities, consistently taking his clams to smash against the same, well-worn spot of coral.

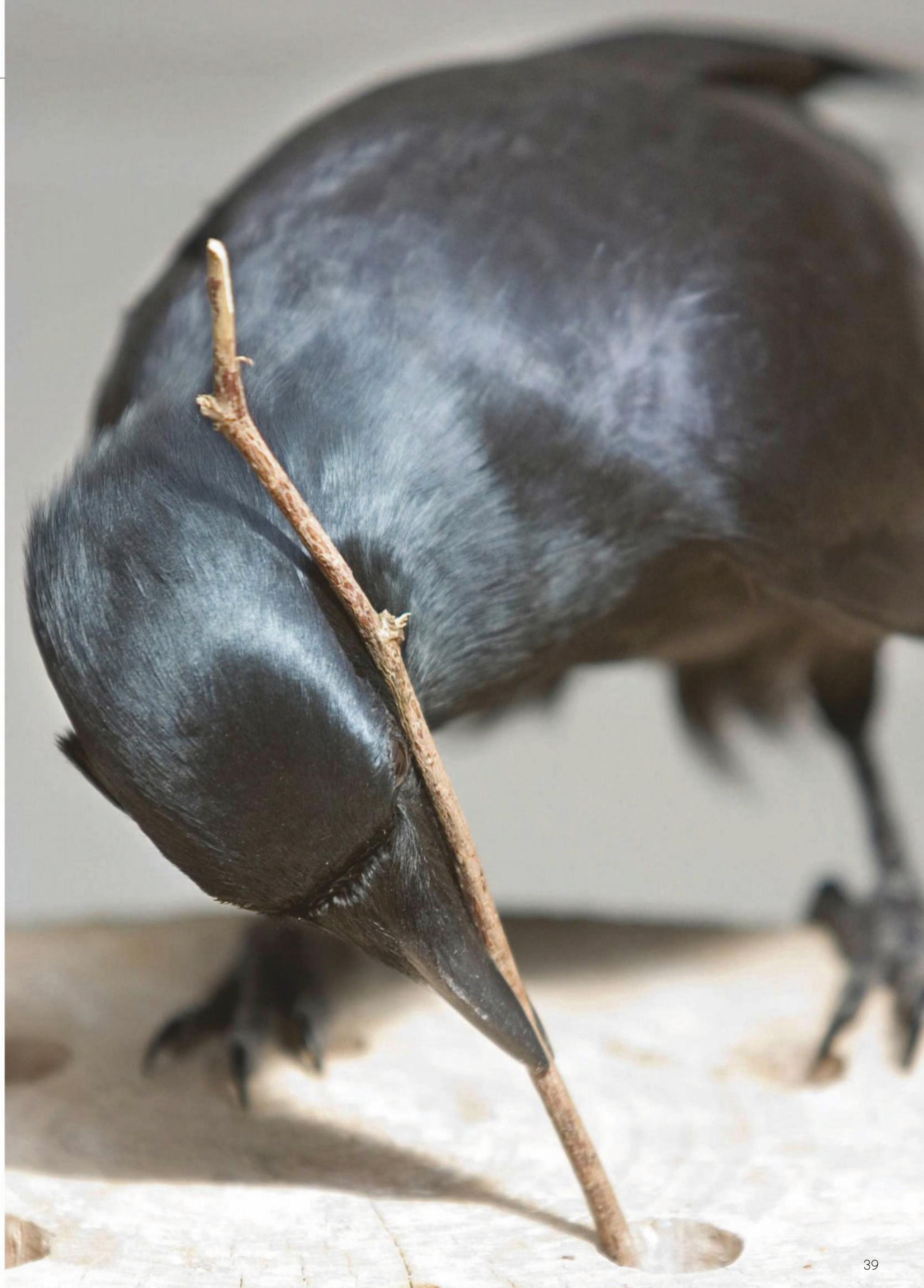
CREATURES OF HABIT?

NEW CALEDONIAN CROW →

In 2002, Betty the New Caledonian crow captured attention worldwide by bending a wire into a 'hook' and using it as a tool to extract food from a tube. Some scientists took this as a sign of superior intelligence, claiming Betty was problem-solving in a spontaneous way. However, further studies showed that wild crows – like the one in this photo – are just as adept at making hooks, but from twigs. Research suggests that the crows' tool use comes from watching other crows initially, but they also seem to commit the shape of the hooks to memory. "Like having a phone number in your mind and then using the memory of that phone number to make a call," suggests Dr Nathan Emery, a crow expert at Queen Mary University of London (QMUL). If this is what's happening, then crows are more creatures of habit than creative thinkers.



LUCY HOCKINGS/BBC, DR SIMON WALKER





SLICK AS A PARROT

GOFFIN'S COCKATOO ↑

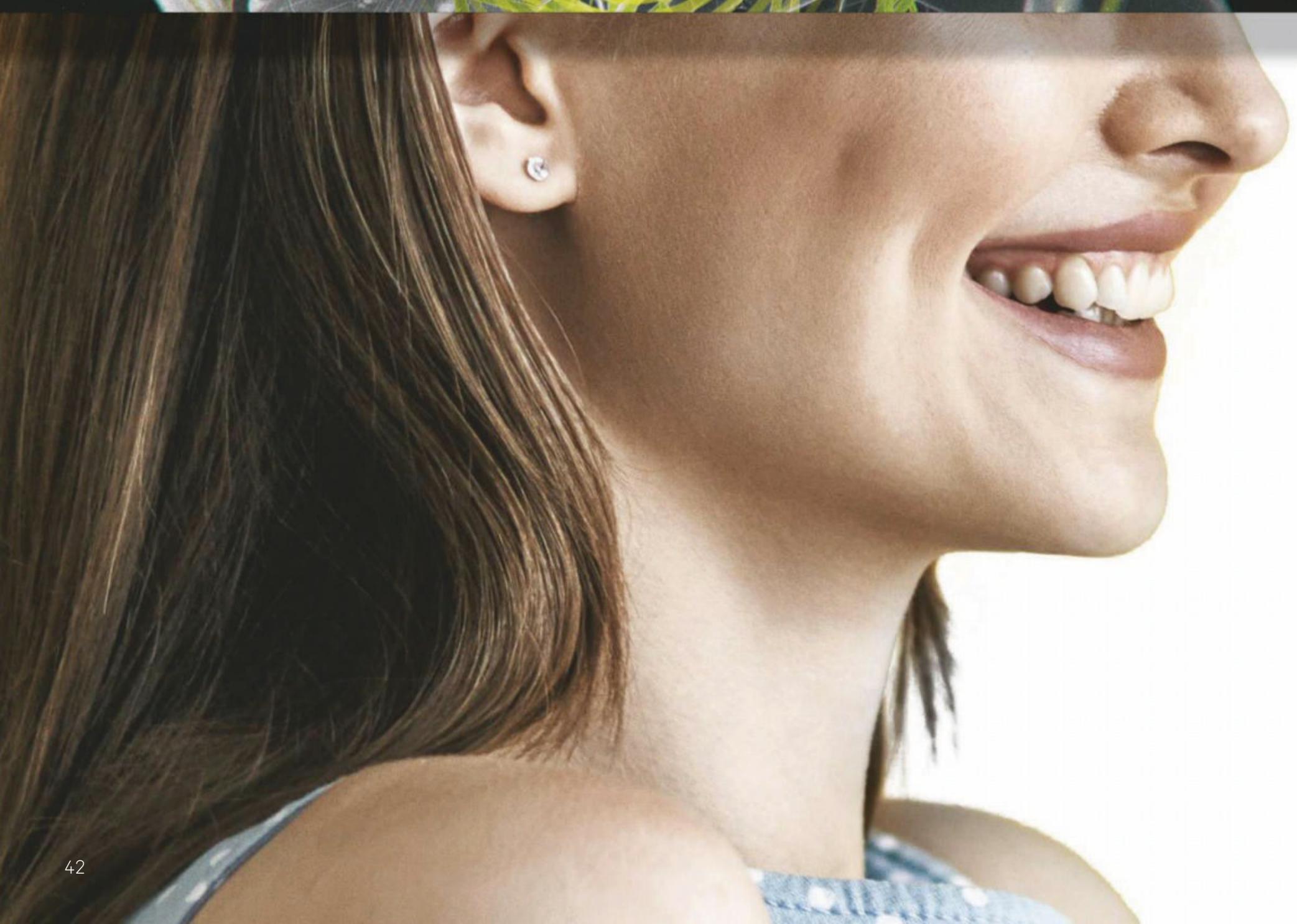
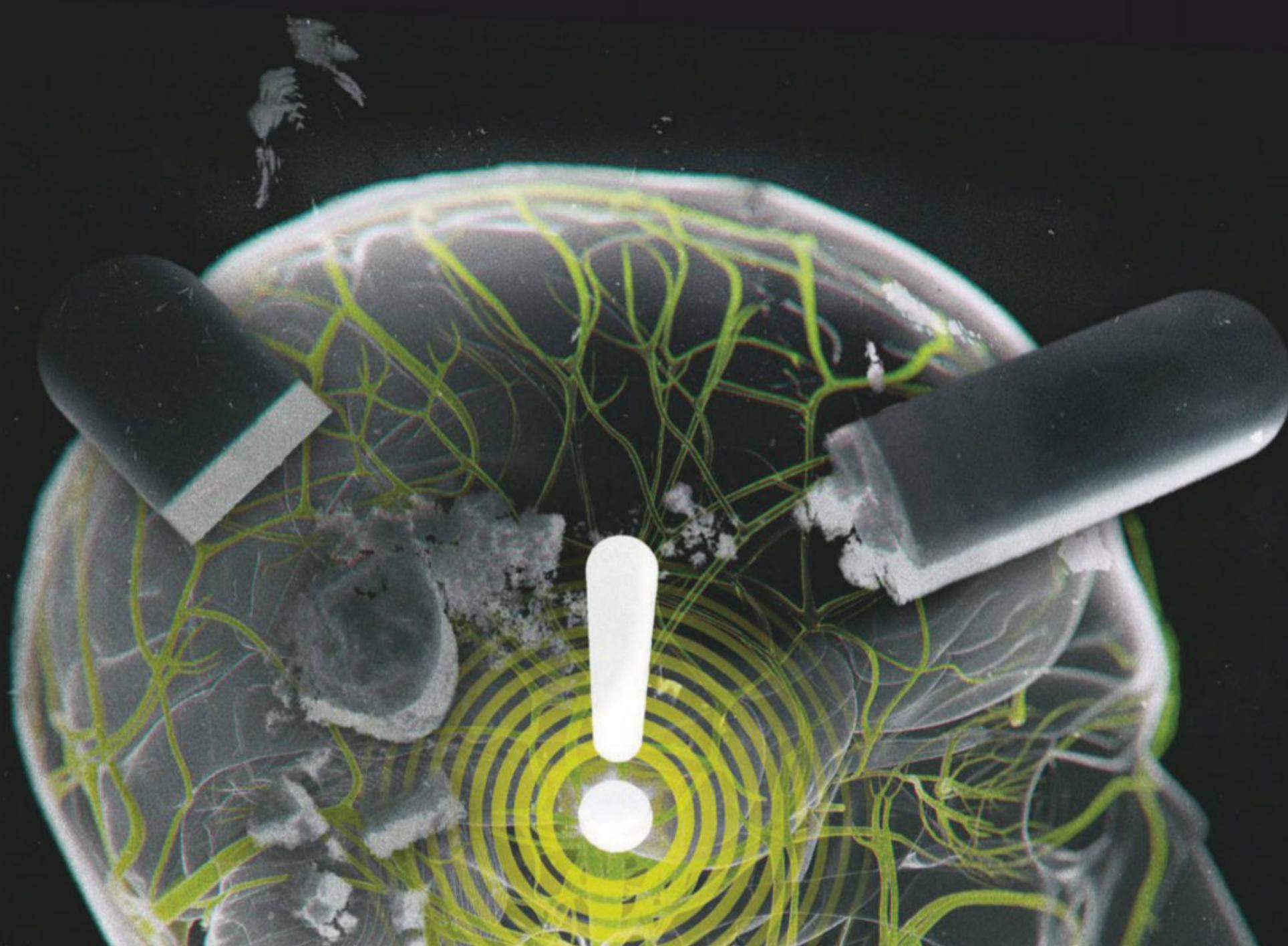
A couple of years ago, biologists at the University of Vienna revisited Betty the crow's famous hook-making experiment with Goffin's cockatoos (seen here) and discovered that the birds could bend pipe cleaners to get food out of a tube, even though they'd never seen or used a hook tool before. What's more, Emery's team at QMUL had already shown the same was true of rooks that were given flexible wires. Neither bird is thought to be a toolmaker in the wild. So what's going on? "If they're making a hook on the first trial, there's no opportunity for them to learn to do it elsewhere," says Emery. "It may be that they're doing it by generalisation from things that they've learnt in the past." Sounds like smart thinking for a bird brain.

THE NUTCRACKER

BEARDED CAPUCHIN MONKEY →

Some bearded capuchins crack cashew nuts with rocks, placing the nuts on hard surfaces that they use as anvils. Primatologist Dr Lydia Luncz from the University of Oxford says it's a trick that's been passed from one generation to the next, although not all capuchin communities do it. Like in humans, tool use is cultural. Luncz studied a group of bearded capuchins at Brazil's Serra da Capivara National Park. Here, as well as using stones for nut-cracking, they use them as a shield against toxic substances that spurt out of the cashew shells. The monkeys also use stones to dig for tubers and spiders. In some groups, females use stones to flirt, throwing them at males that they want to mate with in order to get their attention. SF





No more pain

Imagine never getting hurt. You could break your arm without blinking and give birth without breaking a sweat. This is reality for the people who feel no pain and their secrets could help the rest of us switch off our suffering

by SIMON CROMPTON

For centuries the problem of pain has eluded easy answers. It's part of everyone's daily life and causes constant agony for the millions suffering from chronic conditions that refuse to respond to treatment. Now, though, new answers about the nature of pain are emerging not from the everyday, ordinary experience of it but from the extraordinary: from the handful of people who don't experience pain at all.

These 'real-life X-Men' are pain-free from birth because of genetic mutations. And studying them is revealing that, amid all the other complex contributors to the way we feel pain, the role of our genes may be crucial.

BURNS, BLEEDS AND BRUISES

Until she was in her 60s, Jo Cameron, 71, thought she was just like everybody else – a bit more accident-prone, carefree and happy-go-lucky maybe, but not in any ways that would set her apart.

Except that when she burned her arm on the cooker it was the smell of burning flesh, not the pain, that

alerted her to the injury. And when she cut herself, she only noticed when she spotted blood dripping from the wound. And when her car was run into a ditch and overturned, she climbed out and went to help the driver of the other car involved in the crash while paying no heed to her lacerations and bruises. "My brain doesn't stop me from doing things, which is stupid really," she says.

It was only when Jo had a notoriously painful hand operation that doctors picked up on her complete inability to experience pain. Before the procedure

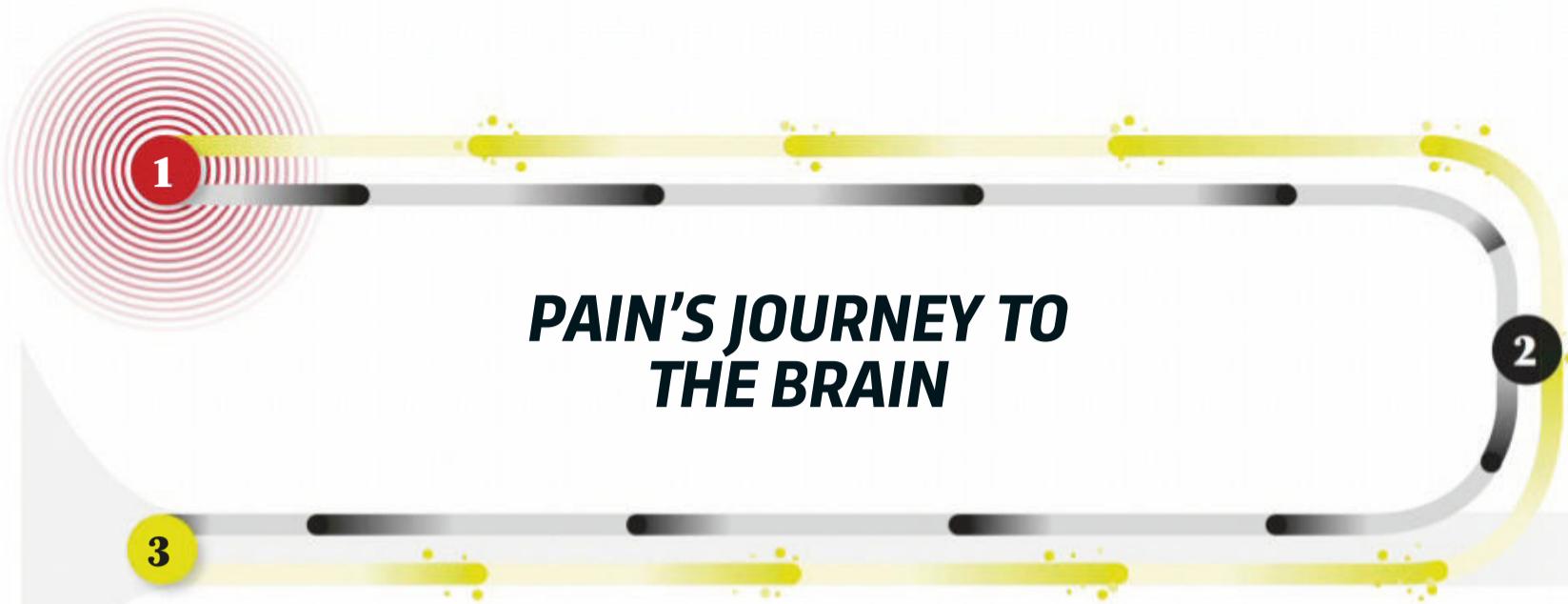
"IT WAS THE SMELL OF BURNING FLESH, NOT THE PAIN, THAT ALERTED HER TO THE INJURY"

she had teased the anaesthetist that she wouldn't need any painkillers after the surgery and he was dumbfounded when, visiting her hours later,

he found that she had been as good as her word. Not a single paracetamol had passed her lips.

In the months afterwards, Jo worked with the consultant anaesthetist, Dr Devjit Srivastava from Raigmore Hospital, Inverness, and molecular biologist Dr James Cox from the Wolfson Institute for Biomedical Research at University College London to find out more about her remarkable blitheness to pain. Thanks to our increasing ability to analyse the human genome, they discovered that Jo was one of a growing, but still tiny, group of people in the world who have genes that render them impervious to pain.

In Jo's case, they found that she had a mutation in a gene that controls the FAAH (fatty acid amide hydrolase) enzyme. This enzyme controls release of a brain lipid called anandamide, which binds to cannabinoid receptors on the surface of cells – part of the chemical system by which cells signal each other about pain, appetite, mood ➤



PAIN'S JOURNEY TO THE BRAIN

1. STIMULATION

Potentially harmful stimuli – such as pressure, heat, damage – are detected in receptors called nociceptors found on the skin or within organs and tissue. Aggravation of nociceptors causes changes in the distribution of charged particles in and around the nerve cell, which generates an electrical signal.

2. TRANSMISSION

If the electrical signal generated by the nociceptors is strong enough, it passes to adjacent nerve cells (neurons). A weak signal won't travel far enough to reach the spinal cord, so you don't experience the pain. But a strong signal propagates along neurons from the nociceptors all the way to the spinal cord.

3. RECEPTION AND RESPONSE

Nerves in the spinal cord transmit the signal to the brain. The somatosensory cortex of the brain receives the input and interprets it as pain. The brain releases pain-suppressing chemicals (such as endorphins) and increases blood flow to the injury site, to promote healing and fight off invaders.

• and memory. Anandamide effectively mimics the effects of cannabinoid drugs. Animal experiments have already shown that inactivity in the FAAH gene results in more circulating anandamide – resulting in them being mildly spaced out, with less pain, improved mood and poorer memory. It's no surprise, then, that anandamide has become known as the 'bliss molecule'.

Jo also displayed a deletion in part of an associated gene called FAAH-OUT, which seems to have a role in regulating FAAH. This genetic oddity has excited scientists because targeting FAAH-OUT provides a possible new route for developing pain-control drugs.

Jo's son also has the FAAH-OUT microdeletion (and she suspects her father did too), but not the FAAH mutation, so Jo may be an extreme case. She has almost double the normal amount of circulating anandamide in her system, which may explain why she was violently sick when given morphine after her hip operation. "It was like having an overdose because I already have masses of painkiller in my brain. For the first time in my life I felt really ill."

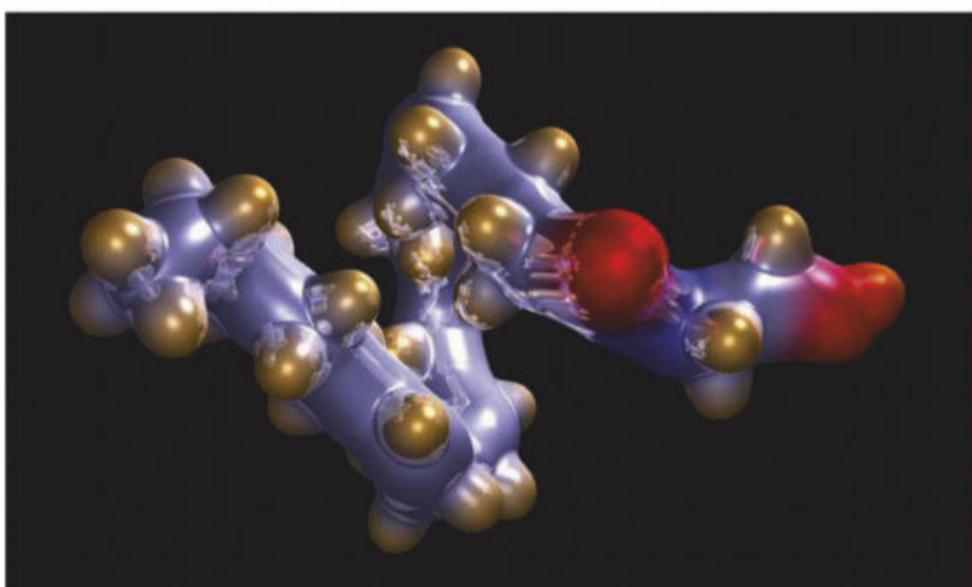
The anandamide may also explain Jo's exceptionally positive and healthy disposition. Jo says she is constantly losing things and doesn't worry about anything.

"PAIN IS A WAY TO TEACH YOU ABOUT POTENTIAL HARM IN YOUR ENVIRONMENT; A WAY TO DRIVE YOUR MOTIVATIONAL SYSTEM SO THAT YOU CAN AVOID DANGER"

"I'm happy about most things, which I think can be quite annoying for my family," she says. "My father was the same." Even when her first husband died leaving her to look after a young child, Jo wasn't overwhelmed with grief or anxiety. "I was very sad obviously, but I just coped. I missed him, but I just got on. If everything goes wrong I go into practical mode. I don't go into the depths about anything."



LEFT Jo Cameron possesses an uncommon genetic component that leaves her practically unable to feel pain



ABOVE Anandamide molecules play a role in memory and pain relief

Her memory, she says, is hopeless. “The number of expensive new car keys my husband has had to buy because I lose everything – I put things down and I haven’t a clue where they are.”

All these characteristics can be explained by Jo’s elevated levels of anandamide. Studies looking at a loss of FAAH function and raised anandamide have found it results in decreased pain sensitivity, erasure of fear memories, reduced anxiety and

short-term memory problems. It also results in accelerated wound healing, which explains Jo’s remarkable powers of self-recovery.

“I cut myself all the time but you can barely see any of the scars. When I’m sunburned you can see some white marks, but I do heal really quickly, which is strange.”

NO PAIN, NO GAIN

The anandamide is what makes Jo’s case so exceptional. Prof Chris Eccleston, director of the Centre for Pain Research at the University of Bath, says that it’s unusual for people without pain to stay healthy until later life.

“If you’ve never experienced pain and you don’t have fear of harm, your brain never develops that part of your cortex,” he says. “Pain is a coach: a way to teach you about potential harm in your environment; a way to drive your motivational system so that you can avoid danger.”

In truth, most of us need pain to learn and survive. According to social psychologist and author Dr Brock Bastian, we need pain to feel happiness. “We need pain to provide a contrast for pleasure,” he writes. “Without it, life becomes dull, boring and downright undesirable.” But Jo’s personal chemistry seems to help her override this hard truth. ➤



● But she is by no means unique in being unable to feel pain. For decades scientists have studied pain-free people in the hope of understanding pain better. Many have had a group of diseases called HASANs (hereditary sensory and autonomic neuropathies), which means that their nociceptors – the nerve cells that send pain signals to the brain and spinal cord – do not function properly. These conditions have a genetic source and run in families.

But recently researchers using gene-sequencing technology have been able to trace other genetic characteristics that aren't associated with disease or damaged pain-sensing cells but which seem to influence the signalling of pain in all of us.

Dr James Cox, senior lecturer at UCL, is among the leaders in this field and over the past 15 years has worked with families who have inherited pain insensitivity. In 2006, he was part of the team that found three families from northern Pakistan who were completely immune to pain because of a mutation to the gene called SCN9A, which regulates a nerve-signalling mechanism called sodium channel Nav1.7.

More recently he studied a pain-insensitive family in Italy and found that a mutation of a pain signal regulating gene called ZFHX2 was responsible.



ABOVE Ludovico and Letizia Marsili, from Italy, have both been studied by Dr James Cox, as they do not suffer from pain

Together, the research suggests that genes affect our pain in two ways: by regulating the amount of natural painkillers in our system, and by regulating the chemical and electrical channels along which pain signals are transmitted.

Each time such research has been publicised, more pain-free people have come forward. Since discovering the families in Pakistan with the SCN9A mutation, more families around the world have been found with the same characteristic. Since Jo's case was publicised in the UK in March this year, 80 families have contacted Cox saying that they have similar experiences and volunteering to be researched.

"We're working through those now," he says. "The common theme is they all have extreme pain insensitivity so I'm hopeful that when we get the DNA in for these guys we'll find further families for research."

The rush of new volunteers is important because it may indicate that being pain-free isn't as rare as once thought. "There are potentially countless people who have similar experiences to Jo," says Cox. "It may just be that genes or mutations haven't been found." But it's also opening the door to finding other genes that are important in the pain system and could lead to new and better targets for pain relief. "There's a massive need for new painkillers," says Cox.

Many existing painkillers – opioids, for example – are essentially sophisticated versions of herbal medicines. They're not carefully targeted on pain and so are tricky to

"THE RUSH OF NEW VOLUNTEERS IS IMPORTANT BECAUSE IT MAY INDICATE THAT BEING PAIN-FREE ISN'T AS RARE AS ONCE THOUGHT"

LABOUR PAIN IS IN THE GENES

As a result of her rare genetic mutation, Jo Cameron experienced no pain during the birth of her two children. Friends who had given birth before her told her to take every form of pain relief she could get. "I promised them I'd take something as soon as I needed it, but I never did," she says.

New research shows that Jo is by no means a one-off – and the pain experiences of many of us are influenced by our genes. Prof Geoff Woods and a team from the Cambridge Institute for Medical Research have found a more common genetic trait that seems to confer on some women a relatively pain-free state during labour.

Examining a group of 196 women who didn't request or require analgesia during their first labour, he found "a significant overrepresentation" of a rare, but by no means one-off, variation in the gene KCNG4. The genetic variation seems to affect pain channel signals from the sensory neurons in the uterus.



dose, which can lead to addiction, overdose and unpleasant side effects. At the same time, around one in five people is living with chronic pain and for some, pain won't fade whatever medications are used.

So the pharmaceutical industry, aware of this and the publicity surrounding an opioid addiction epidemic, is paying close attention. Drug companies have picked up on the significance of the SCN9A mutation and have been investigating specific blockers of sodium channel Nav1.7 as possible new targeted painkillers.

THE MULTIFACETED NATURE OF PAIN

Eccleston says there's no doubt that the genetics of pain has, until recently, been under-researched. "It's still a very small part of what people are doing because, although we have new methods to examine the genetics, pain is a tremendously complex system, and it's still difficult to know where to look for the right pain transduction mechanisms."

What's important, he says, is that in the search for cures for pain that won't go away, genetics is not looked at in isolation from other contributors, such as stress, environment, psychology and age. The new field of epigenetics – the way that our environment changes the way our genes express themselves – is also crucial, he says.

"We need to know why some people develop refractory pain, whether there's a genetic predisposition to that and what makes that predisposition express itself," he says.

On a human level, perhaps what's most intriguing about the hundreds of pain-free people turning up around the world is that they exist at all. On the face of it, there is no evolutionary advantage to feeling no pain. It increases the risk of injury from cuts, blows and knocks that cannot be felt. Life is likely to be short, because the brain is less likely to learn self-protection strategies.

Yet here is Jo, approaching old age, active, healthy, bubbling with enthusiasm for life and feeling just as she always has, that living without pain is normal. That's all that millions of people in constant pain could ever want. And Jo feels her genes may be able to help them: she's happy to keep stepping into the public eye to promote the research, to ensure it continues. "It's unbelievable, all the interest," she says. "I'm a very ordinary person." SF

by SIMON CROMPTON

Simon is a science journalist and former medical editor on The Times.



BBC
FOUR

Watch *You, Me And Eugenics*, with Angela Saini and Adam Pearson, later this year on BBC Four. Check *Radio Times* for details.



WE LIKE TO THINK OF SCIENCE AS BEING BALANCED, ACCURATE, AND DEVOID OF PREJUDICE. YET ACCORDING TO ANGELA SAINI, RACISM IS INSIDIOUSLY WORMING ITS WAY INTO RESEARCH. SHE TALKS TO ALICE LIPSCOMBE-SOUTHWELL

WHY DID YOU DECIDE TO WRITE A BOOK ABOUT RACE SCIENCE?

I grew up as an ethnic minority in London at a time when it was a very racist place, during the 80s and 90s. For me, the big event that kind of overshadowed my teenage years was the Stephen Lawrence murder – I lived quite close to where he was killed. It was quite a dark place anyway: the BNP bookshop was nearby and they used to march in my town quite regularly. This is the book I always wanted to write. I think we're living in an age when there's a rise in racism, the far right and nationalism. I never imagined that politics would take such a dark turn again, but here we are.

Whatever else is happening in science, over the last 50 to 70 years race has crept back into the discourse. We're constantly told race is a social construct and has no basis in biology. Yet when you look at what population geneticists write, or what medical researchers write, they're constantly using racial categories as if they're real.

I wanted to get to the heart of that. Which is it? Is race real? Or is it a social construct? And if it's muddier than that, then where do the blurry lines lay and how can we understand them?

YET MANY SCIENTIFIC STUDIES STILL SPLIT PEOPLE BY RACE, BY SAYING THAT AFRICAN-AMERICANS OR HISPANICS ARE MORE LIKELY TO GET CERTAIN DISEASES, FOR EXAMPLE...

We have to remember the US guides the rest of the world when it comes to this kind of research. For quite a while they've been collecting data by race. And just having that data invites comparisons, which then causes problems. But also in America, race, class and social status all run along the same lines. So, black Americans still live in much worse circumstances, on average, than white Americans. They're more likely to live in poorer areas, to be exposed to toxic things, to have poorer diets, poorer education systems and poorer access to healthcare than white Americans. Black ➤

PHOTOGRAPHY BY ANDREW COTTERILL WITH SPECIAL THANKS TO THE V&A MUSEUM LONDON

► Americans die at a greater rate than white Americans in almost category, even infant mortality, which is quite shocking. To look at that and suggest that it's down to something genetic and innate to black Americans, to me, is just bizarre. That this one group should be so biologically disadvantaged that they would die of everything at greater rates than everybody else just beggars belief. And yet, what you repeatedly see in the medical literature is that we are looking for genetic reasons for these health disparities. You don't need to look at genetics because there are so many other explanations for why these gaps exist.

ARE THE TRENDS YOU SEE IN AMERICA REPLICATED IN OTHER PARTS OF THE WORLD?

No, and again, weird and elaborate explanations are used to explain why black Americans suffer disproportionately from so many diseases, when black Africans don't. So, for example, hypertension. Black Americans have higher rates of hypertension than white Americans. Black Britons have higher rates of hypertension than white Britons – in fact, NICE [National Institute for Health and Care Excellence] guidelines advise doctors to give different drugs to patients under the age of 55 if they're black than if they're white. Now, why do they do this when we know that the lowest rates of hypertension in the world are in Africa, and the highest adjusted rates of hypertension in the world are among the Finnish, Russians and Germans. Yet there's this lingering belief that there is something about these communities and how they evolved that makes them different. But the evidence for that just isn't there.

In America, drugs are targeted at black people, at Hispanic people. And you have to remember, Hispanic means absolutely nothing genetically. This is a group of people so hugely disparate in their ancestries. Being Hispanic could mean that you have African ancestry, or European ancestry, or Native American ancestry. Even at a deeper level, there is little genetic basis to race anyway. And that strikes us as surprising because we think we are all different, but we all completely overlap and it's only at the margins that you see a tiny bit of difference. It is perfectly possible for me to have more in common genetically with my white neighbour than with my Indian neighbour. But we don't think of it that way. We think that because of my Indian heritage, I'll have more in common genetically with every other Indian on the planet, but that's not the case.

IT SEEMS THERE IS STILL A WIDESPREAD BELIEF THAT THERE ARE DIFFERENCES THOUGH...

Yes. And I think it's an easy thing to do. We look at the world, we see the preponderance of certain



people doing certain things and we conflate that with our existing ideas about race. We categorise so easily.

Over the last few hundred years, categories have been created that have been so important socially and politically. These categories are the basis of subjugation, repression, slavery, colonialism... Our politics is steeped with it and because of that our cultures are steeped with it. We just can't think outside these categories and so every piece of information we have about human difference gets reframed within these categories. But when you know the genetics of it, it doesn't make any sense. It just doesn't, they don't tie up with each other.

SO, HOW DID SCIENCE FIRST START GETTING TANGLED UP WITH RACE?

In relatively recent history – I'm talking about the last few thousand years or so – whenever you have dominant groups, their power begins to be framed as natural, as well as just political or a product of historical factors.

One of the examples I look at in my book is India. The caste system there is essentially like a class or a racial hierarchy. It's a biological system that says, by dint of your birth, this is your place in the social hierarchy. That has been around for hundreds of years, possibly thousands. This is a group of people saying that they are biologically superior to everybody else, and the people below them in the hierarchy have their places and have to stick to those places. There is little sense of social mobility. Things have changed in recent years, but that ➤

Freed black Americans following the US Civil War

Angela Saini

Angela Saini is an award-winning science journalist and broadcaster. She has two masters degrees, one in engineering from Oxford University and another in science and security from King's College, London. She has been the recipient of the American Association for the Advancement of Science's Kavli Science Journalism gold award and was named the European Science Journalist of the Year by the Euroscience Foundation in 2009. Her new book *Superior: The Return Of Race Science* is released on 30 May.

“YOU DON’T NEED TO
LOOK AT GENETICS
BECAUSE THERE ARE
SO MANY OTHER
EXPLANATIONS FOR WHY
THESE GAPS EXIST”



"IT'S BECOME EMBEDDED WITHIN THE SCIENTIFIC METHOD AND THE WAY WE CATEGORISE PEOPLE"

● prejudice is still there. There's no doubt. These ideas about natural superiority and dominance have been there for a long time. And you first see the science of race emerging during the Enlightenment. At the birth of modern, Western and European science, scientists like Carl Linnaeus [the Swedish botanist] started the taxonomies of the natural world and, of course, started with humans. And, again, the sense of a hierarchy was there, that the white man – and we have to remember that women were slotted into this hierarchy below men – is the most superior. Quite convenient for all these white, male, European scientists that everyone else happened to be inferior to them. And this is how it continued.

WHAT WAS THE MOST SURPRISING DISCOVERY YOU MADE WHILE RESEARCHING THE BOOK?

It was a very personal journey for me, and painful in many ways because these are issues that have affected me my entire life. But now with the rise of the far right, it hits home even more. You see the kind of gross manipulation of the sciences – not just by people outside the sciences, abusing science because of their politics; this is scientists abusing science. It's become embedded within the scientific method, within the structures of science and the way we categorise people and think about human differences. And I think that, for me, is the darkest and most dangerous aspect of this.

We know that there have been Nazi scientists, that there have been scientific racists. The people who didn't want to let go of segregation in the US, who wanted to maintain slavery, who wanted to maintain colonialism, who want to ban immigration, racial mixing, who don't want people

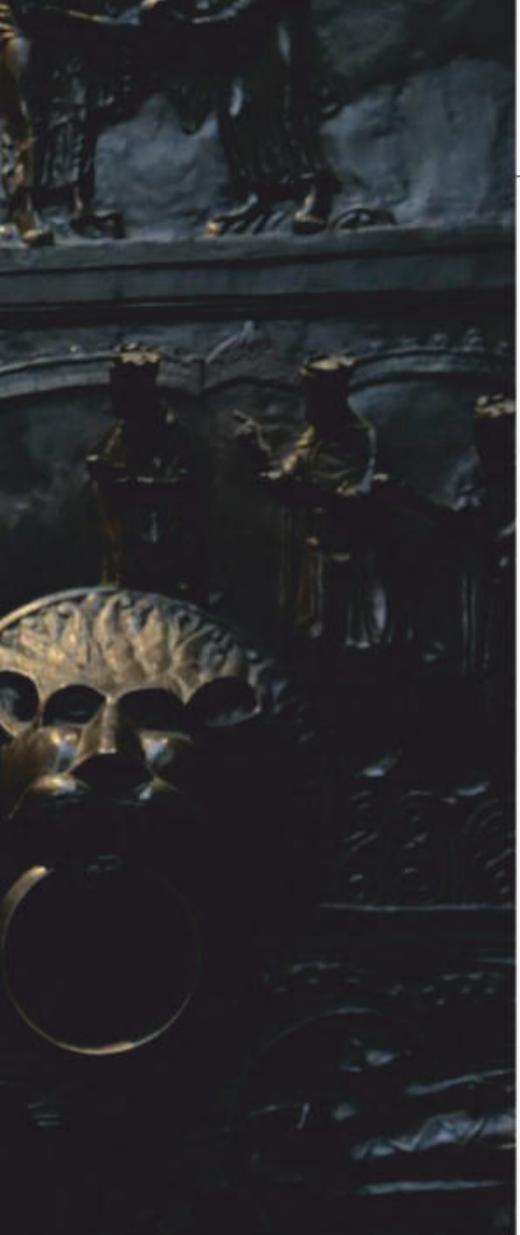


GETTY IMAGES

TOP Angela Saini pictured exclusively for *BBC Science Focus* in the V&A Museum's West Court

ABOVE The caste system was used to organise Hindu society for centuries

to have babies with people of different races or heritages. Those people have always been there and, frankly, I wonder if they'll always be there because there will always be hateful people like that in the world. What disturbs me more is that mainstream, good, liberal and well-meaning scientists have also not let go of these ideas. They keep bringing them back in the way they think about difference. Not necessarily because they're racist, but because they still exist in the racist frameworks that existed in the past. We all do.



DISCOVER MORE

BBC RADIO 4 LISTEN

Listen to Angela talk about racism in science on BBC Radio 4 in October.

ON THE PODCAST

From June, you can listen to our full interview with Angela on the Science Focus podcast at sciencefocus.com/science-focus-podcast

That's the way we all think about these things in this way. It's really hard to abandon it.

WAS IT DIFFICULT INTERVIEWING SCIENTISTS WITH EXTREME, FAR-RIGHT, OR RACIST VIEWS?

I've encountered racism my whole life. It's not a new and shocking thing for me to suddenly hear an intellectual saying it. I'm more used to folks on the streets saying it, so that's perhaps the biggest difference. It's a mistake to think that racists are just uneducated, ignorant thugs. They are also people in power; they're professors at universities; they're editors of journals. People who have never been fully convinced that race is just a social construct and would like to revive race science. Is it racist to want that? That, I think, is where the fuzzy line lays. I'd say it is, because race was just invented. It was never born out by biology and their failure to understand that betrays their racism.

But we see this argument more and more. People calling for a return to this kind of research under the banner of diversity of opinion or academic freedom. And to some extent, universities are entertaining them. It's only fairly recently that Jordan Peterson [the contentious Canadian psychologist] had his invitation to Cambridge University rescinded, despite his work being panned, globally, for not being very scientific and for him entertaining the ideas of Charles Murray, the co-author of *The Bell Curve* [a controversial book that claims to examine the connection between race and intelligence]. These ideas are being entertained because they're coming from within the academic establishment and that's what we have to watch out for.

The history of race science is a lesson in itself for how easy it is for science to get stuff wrong and how scientists can stick with bad ideas. So, while I have faith in the scientific method as a way of understanding the Universe, I don't have complete faith in scientists, or the scientific establishment, to do that completely responsibly. And that's because we are all human and we all have our own politics. And whether we like it or not, there are scientists out there who have far-right views.

ARE YOU CONCERNED THAT RACISM WILL CONTINUE CREEPING INTO SCIENCE?

I think we need to have a really thorough rethink, because I think it's creeping in more and more. One of the reasons is ancestry testing, I think. In a way, population genetics [the study of genetic differences between and within populations] gave birth to ancestry testing and it's reinforced the idea that race is real. Because you go and have a DNA test done and it tells you you're 96 per cent south Asian, or 50 per cent this and 50 per cent that. Well, how can it do that unless there is some genetic basis

to race? That's the kind of paradox that we're dealing with here. On the one hand, we're told race isn't real and on the other you have a DNA test telling you that it is. Scientists know there are tiny statistical differences between population groups, and the DNA companies then conflate these with social categories of race. And what genetics and ancestry testing does is create the illusion that there is more to this than there is. At the end of the day, that's the scientists' fault. It's not the DNA companies' fault – they just took what they were given.

DNA TESTS CAN TELL YOU HOW MUCH NEANDERTHAL YOU'VE GOT IN YOU. CAN YOU TELL US ABOUT THE CHANGING VIEWS OF NEANDERTHALS?

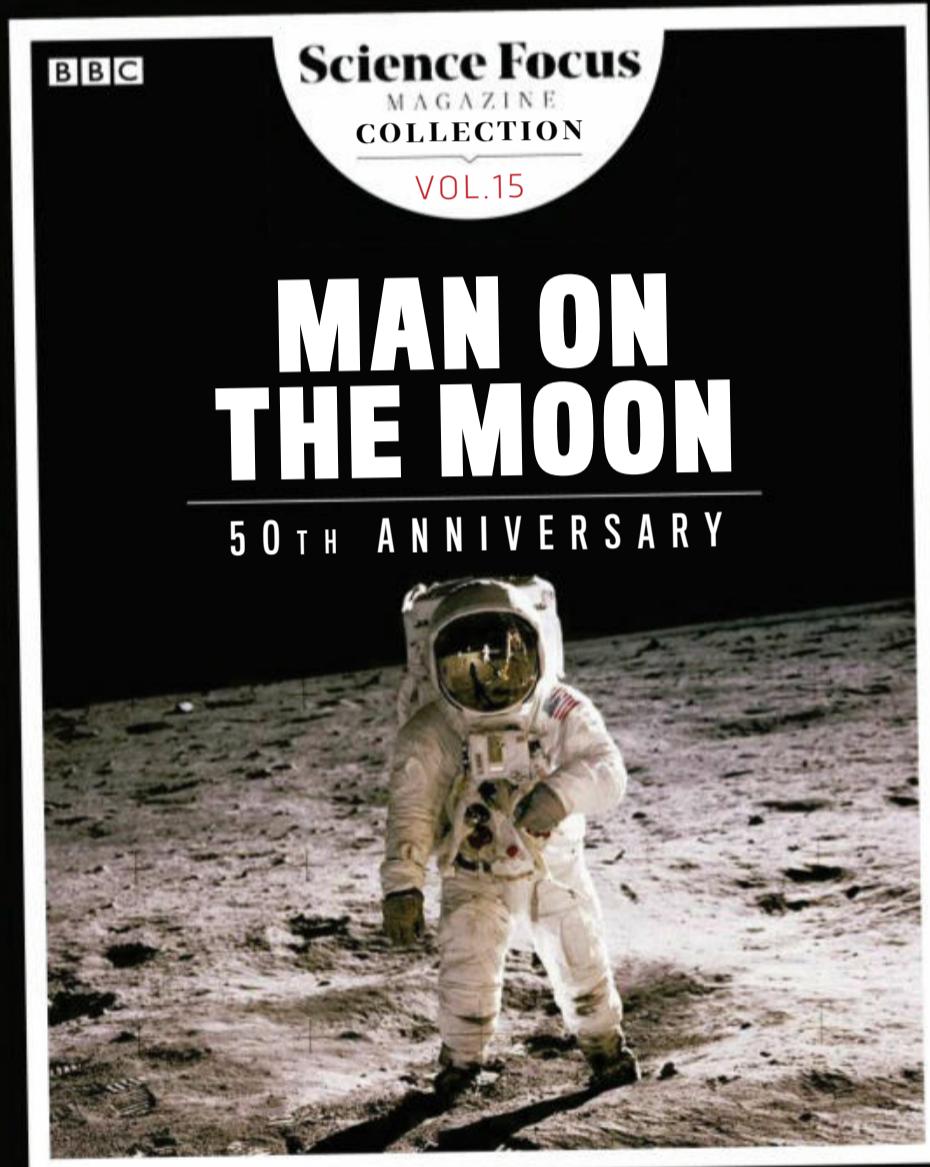
Historically, when Neanderthal remains were first discovered, what did European scientists do? They compared them to Aboriginal Australians. And the reason they did that was because they thought that Aboriginal Australians were somehow lower down the evolutionary ladder, and so were Neanderthals. Aboriginal Australians were treated abominably, physically degraded and deliberately wiped out. To me, it feels like genocide how these people were treated. The race science was always there, this idea that, somehow, they were doomed to go extinct because they were like the Neanderthals, and that the more superior, evolved humans would come along and supplant them. And that this was somehow nature's way.

But then we see that Europeans have some shared heritage with Neanderthals and suddenly they undergo this huge image change. The number of articles I've read recently saying that Neanderthals were smarter than we first thought, that they were wiser, that they were more sensitive, that they were wiped out not because they were stupid, but because of some kind of unfortunate consequence of history. How the hell did this happen? How did we get to here? We know next to nothing about the Neanderthals. What we're doing is projecting our ideas of what they must be based on our racial ideas of who we are. And this is a perfect example of the kind of pernicious legacy of race science. That within this one story, we can see just how much we still buy into the idea of a racial hierarchy.

But I think it's important to remember that this isn't like a white disease. It's not white people who do this to everybody else. We all do it to each other. In India you see the caste system. In China it's still taught that the Chinese people did not originate in Africa, that they evolved from an early form of *Homo erectus* in China. And again, this serves myths about who we are and that we have a particular claim to superiority because we are different. And you see it everywhere. I think that's a sad thing. You see it everywhere. SF

MAN ON THE MOON

50TH ANNIVERSARY



Celebrate the golden anniversary of the first Moon landing with this *BBC Science Focus Special Edition* and retrace the journey from the start of the space race to the moment Neil Armstrong took his historic small step

IN THIS ISSUE...

- How JFK inspired a nation to win the space race
- Meet the NASA rocket scientist with a dark past
- Neil Armstrong on his emergency lunar landing
- The women who were key to Apollo 11's success
- Experts explain why we should return to the Moon

PLUS – subscribers to *BBC Science Focus Magazine* receive FREE UK postage on this special edition

**ONLY
£9.99
INC. FREE UK POSTAGE***



How the two most powerful nations on Earth became locked in a race to the Moon



Explore the Saturn V rocket that blasted the Apollo 11 crew into space



Neil Armstrong describes what it was like to land on the Moon for the first time



Pre-order online
[www.buysubscriptions.com/
manonmoon](http://www.buysubscriptions.com/manonmoon)



Or call 03330 162 138[†]
and quote Man on the Moon PRINT 1

HOW MUCH SLEEP DO YOU REALLY NEED?

Bad news for people who love to boast about only needing four hours a night...

Recently, I celebrated my 62nd birthday. On the whole I am in pretty good shape, but one of the most annoying things about ageing is that over the years my sleep has become shallower and more fitful. These days I rarely get more than seven hours sleep a night, and I often get less. So how much does that really matter?

A while ago I was involved in an experiment for the BBC series, *Trust Me, I'm A Doctor*, where we decided to assess the effects of sleeping fewer than seven hours a night. We asked a group of volunteers to come to the University of Surrey Sleep Research Centre. The volunteers were randomly allocated to two groups. One group was asked to sleep for six and a half hours a night, the others got seven and a half hours. After a week, the researchers took some blood samples and the volunteers switched sleep patterns. The group that had been sleeping six and half hours got an extra hour, and the other group cut an hour.

Throughout the study we asked our volunteers to complete computer tests, which showed, not surprisingly, that most of them struggled with mental agility tasks when they'd had less sleep. But the most interesting results came from the blood tests.

Dr Simon Archer, who helped run the study, was particularly intrigued



“**T**here were around 500 genes that were affected by the amount of sleep the volunteers had”

by how changes in the amount of sleep affected their genes. “We found that overall there were around 500 genes that were affected – some that were going up, and some that were going down,” he told me.

When the volunteers had reduced sleep, genes associated with inflammation, immune response and response to stress became more active. The team also saw increases in the activity of genes associated with diabetes and risk of cancer. The reverse happened when the volunteers added on an hour of sleep.

So even an hour's extra sleep a night can make a significant difference. And when it comes to the impact of sleep it's not just about quantity, but quality. A recent study carried out by researchers at the University of Rochester Medical School and published in the journal *Science Advances* showed how much deep sleep you get impacts the glymphatic system, a network of plumbing in the brain that piggybacks on blood vessels and pumps cerebral spinal fluid through brain tissue to wash away waste and toxic proteins like beta amyloid and tau.

Sleep often becomes lighter and more disrupted as we age, so this study reinforces and explains the links between ageing, sleep deprivation, and heightened risks of developing Alzheimer's. So the clear message is that most adults need seven hours of quality sleep a night. The real challenge is, how do you get it? SF



MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *The Fast 800* (£8.99, Short Books).



COMMENT

GAMING = GOOD

World Of Warcraft and similar online games can offer a lifeline to disabled people

When Mats Steen died, his parents, Robert and Trude, thought their son had lived a lonely life. He'd spent much of his time in a dark apartment with only his caregiver for company. And that was a source of great sorrow for his parents, who grieved when Mats had been diagnosed with muscular dystrophy at the age of four, and had been confined to a wheelchair not long after. They lamented that Mats would never climb trees, never fall in love. Never have a 'normal' life. And somehow what they understood about living a full and rich life with a physical disability stopped there.

When Mats was 10, Robert gave him a computer. As his body continued to deteriorate, Mats retreated into it. At 24, he passed away, and that was when Robert's discoveries began.

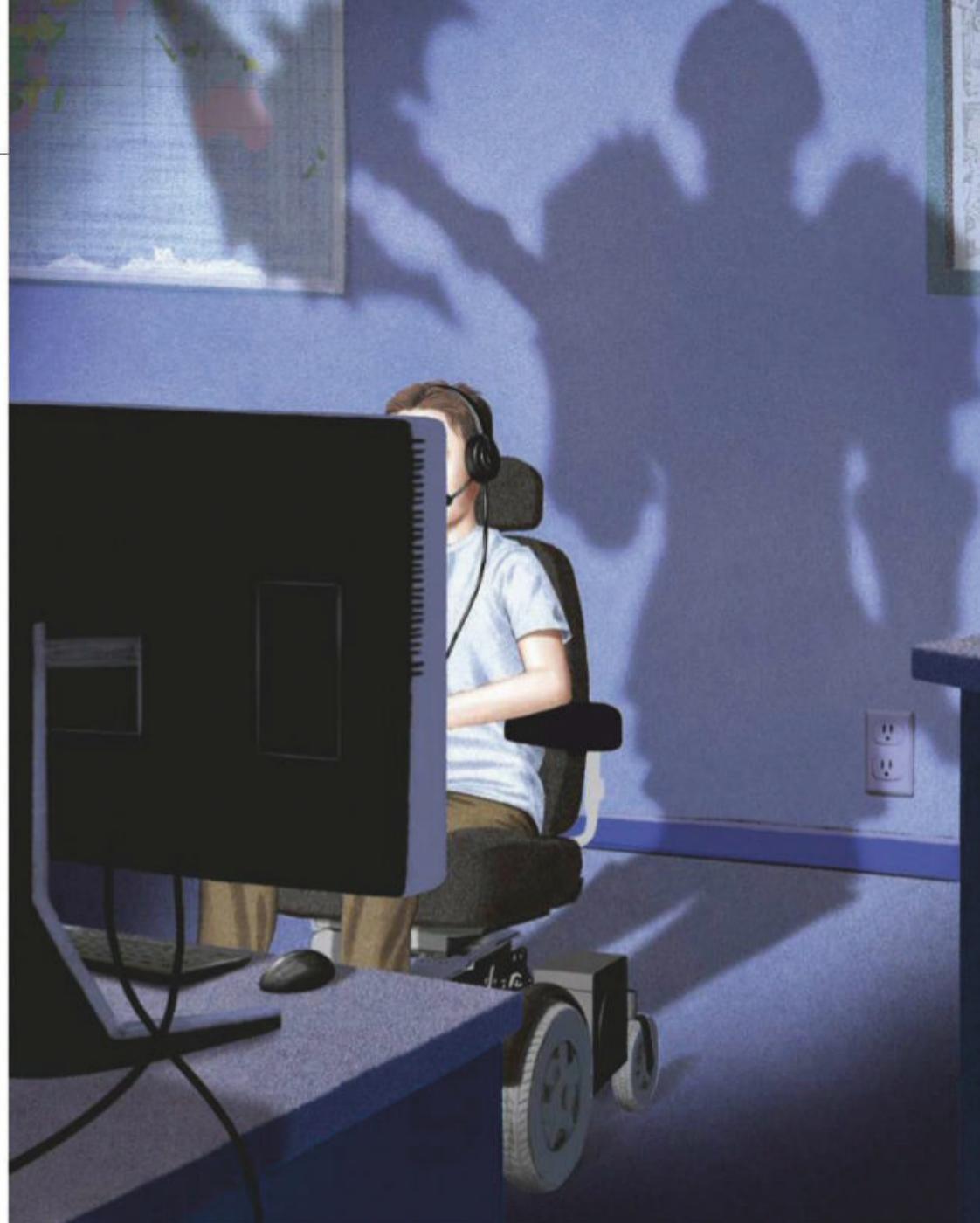
As he was dying, Mats had asked his father to tell his friends that he loved them. But Robert didn't know who he meant. So, after they returned home from the hospital, and during the week they prepared for his funeral, Robert went into the darkened flat and turned on the computer. He posted a note on his son's blog, announcing Mats's death. He didn't expect the hundreds of emails from strangers around the world that poured in, sharing their grief and wishing, somehow, to be part of his offline life.

Inside that machine, Robert discovered that his son hadn't been



ALEKS KROTOSKI
Aleks is a social psychologist, broadcaster and journalist. She presents *Digital Human*.

PORTRAIT: KATE COPELAND ILLUSTRATION: JASON RAISH



“Inside that machine, Robert discovered that his son hadn’t been lonely or solitary”

lonely or solitary at all, but that he'd lived the most extraordinary and rich life, as part of a tight-knit group of hundreds of people who hung out and battled together as a guild in the multiplayer game *World Of Warcraft*. Robert never anticipated that Mats's life would be even greater online.

Most people who don't enjoy online gaming have a little prejudice against the games and those who play them – what can living in a fantasy land possibly offer to anything in the offline world? Well, quite a bit actually. Several years ago, I studied the psychological effects of online gaming on people with severe physical disabilities. People connect and hang out and build friendships

between intense bouts of teamwork. They rely on one another to secure their long-term investments in a character, their relationships and their time in a game. They do things together. And for people who have a disability, for whom the offline world throws up all kinds of physical, social and architectural challenges, they can play on a level field.

Several of Mats's online friends travelled to Oslo for the funeral; one was invited to give a eulogy. He described Mats as someone who always had time to listen, who always gave love when it was needed, and always backed up his team. For more than 10 years, Mats's online life had given him exactly what his parents feared he was lacking – he climbed trees, he ran, he had a raucous social life. He fell in love.

Robert's expectations of what was possible for Mats ignored what his son was truly capable of. What he needed was the right tools. And for millions of people – physically able or not – the virtual world gives them the toolbox they need to be all that they can be. SF

BRING THE WORLD
OF SOUND TO LIFE
THIS SUMMER
WITH CUTTING-
EDGE TECHNOLOGY

summer sound

YOUR
GUIDE TO
THE LATEST
IN AUDIO

Jabra GN

FLARE.
LONG LIVE EARS.

JBL
by HARMAN

move, talk, listen

JABRA INTRODUCES NEXT-GENERATION ELITE
85H HEADPHONE



Key Features

- SmartSound active noise cancellation
- Jabra Sound+ app
- Six built-in mics for crystal-clear calls
- Siri, Google Assistant and Alexa integration
- 36 hours' battery life

If you like to listen to music on the move, are fussy about sound quality but also need to be able to interact with the world around you, then Jabra's new Elite 85h headphone could be for you.

The Jabra 85h has been designed to offer the perfect solution for listening to music while you travel or commute. The circumaural Bluetooth headphones are equipped with no fewer than eight built-in microphones: six of these are there to ensure you can make and receive telephone calls with no drop-out or distortion while wearing the 'phones, with the other two used as part of the Elite 85h's SmartSound smart active

noise cancellation (ANC) system. This will switch on automatically, for instance, if the microphones detect you're on a train; alternatively, you can enable the HearThrough function so that you don't miss important tannoy announcements while you wait on the platform.

The mics don't just turn ANC on or off, though: they'll also detect what frequencies are dominant in the ambient sounds around you, and cut or boost corresponding frequencies in the music to ensure you're getting the best possible listening experience at all times. And thanks to the accompanying Jabra Sound+ app, all SmartSound settings are fully user-customisable, allowing you to tailor the headphones' behaviour and audio output to your own, specific requirements.

Other high-end features include on-ear detection (the headphones detect when you take them off, and automatically pause the music), one-touch access to Amazon Alexa, Google Assistant and Siri, and certified rain-resistance. The headphones will run for 36 hours on a single charge, come with a two-year warranty and are available in Titanium Black, Navy and Gold Beige.

Jabra Elite 85h
£279.99

Jabra GN



TO DISCOVER MORE, VISIT JABRA.CO.UK



Made in
BRITAIN

METICULOUS, ABSOLUTE FOCUS

Never miss a beat

A record's spiral groove is around 420m per side and over this distance, the needle will dance savagely, vibrating at up to 20,000x a second, capturing millions of transients at a micron level. Remaining rock-solid where it matters is Huei, an advanced phono preamp that never loses focus. Microprocessor-controlled and distilled from 30 years of UK amplifier manufacturing, Huei brings the legendary Chord Electronics' precision to vinyl playback.

CHORDELECTRONICS.CO.UK



Huei

• CHORD •

Chaud Electronics Ltd

Long live ears!

FLARE AUDIO IS ON A MISSION TO PROTECT YOUR HEARING

Hearing protection is a hot topic. Factory workers are usually given ear protectors, but there's a growing understanding that anyone who spends a lot of time exposed to high sound levels – from traffic cops to club-goers – is at risk of tinnitus and hearing loss if they're not careful.

That's where Flare Audio comes in: as well as high-end earphones, the company makes a range of earplugs to block noise in a variety of situations. As do many manufacturers, but what's special about Flare Audio's range is the construction. Standard foam or silicon earplugs may prevent audible sound from entering the ear

“The Isolate® ear protectors are the best earplugs I've ever used, great for air travel and very loud concerts!”

Tony Visconti – Grammy Award-winning producer to David Bowie, T-Rex, Morrissey and Iggy Pop

canal, but the sound you do hear can often be muffled and leave you feeling disconnected; they also won't block very low-frequencies which can also damage your fragile stereocilia (the tiny hairs that your ear uses to detect sound). Flare Audio's Isolate earplugs therefore use a denser material: metal, which prevents these frequencies getting to your ears and gets rid of that underwater feeling. They simply turn everything down to a much lower level without losing any of the detail.

There are four models in the range. Isolate and Isolate MINI are self-explanatory – the latter's simply 30 per cent smaller. These aluminium-bodied models will be fine for occasional users, but there are also the titanium-bodied Isolate Pro and Isolate MINI Pro. Titanium, being denser than aluminium, offers the best possible protection against those low-frequency bass sounds. You'll pay a little more, but if you work in very noisy environments it's a worthwhile investment.

SLEEP TIGHT

Flare Audio isn't just good at protecting you from excessive noise, though – the company also makes earplugs for those who simply want a good night's rest! Sleeep and Sleeep Pro again come in aluminium or titanium, with Flare's noise-blocking technology packed into an earplug whose tiny metal core is covered in memory-foam for maximum comfort. Alternatively, Sleeep Flex replaces the metal with flexible silicone so the earplug bends where you do, making it the most comfortable in the range.

Whether you need regular, daily protection from high-decibel

environments or just want to turn the world down when you go to bed, then, Flare Audio have you covered.

Flare Audio earplugs
£24.99–£49.99

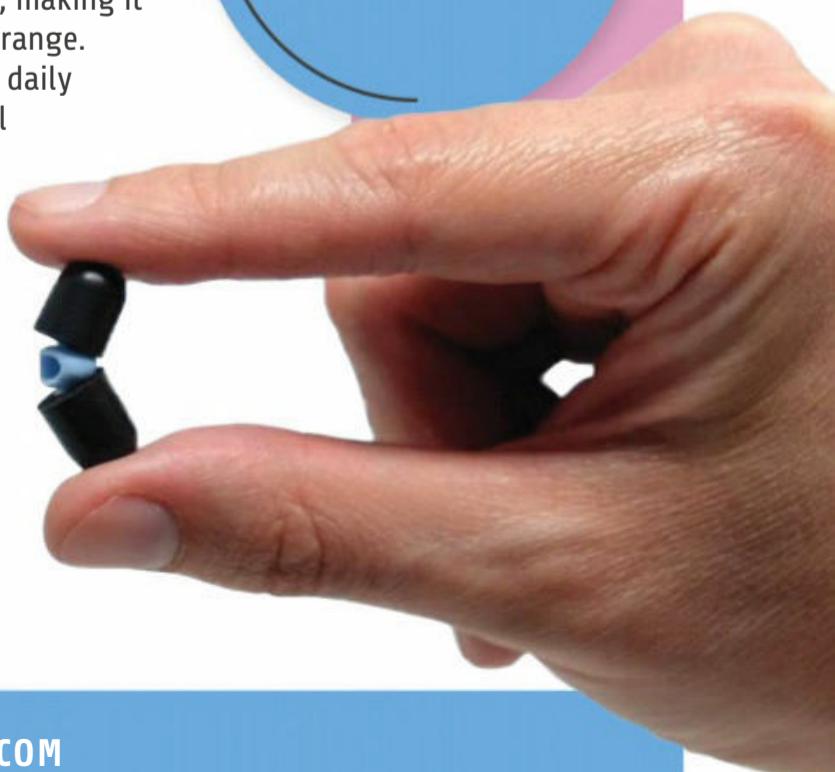
FLARE
LONG LIVE EARS.



Key features

- Made from aluminium or titanium for superior sound reduction
- Tailored to suit a range of user requirements
- Available in a range of colours

summer
SOUND



TO DISCOVER MORE, VISIT FLAREAUDIO.COM

LIVE it up with JBL

JBL'S NEW WIRELESS HEADPHONES COME IN ALL SHAPES AND SIZES

summer
SOUND



JBL has extended its range of wireless headphones with the launch of the LIVE series. The four models in the LIVE range come packed with advanced features and are the company's first Bluetooth headphones designed to work with Google Assistant and Amazon Alexa.

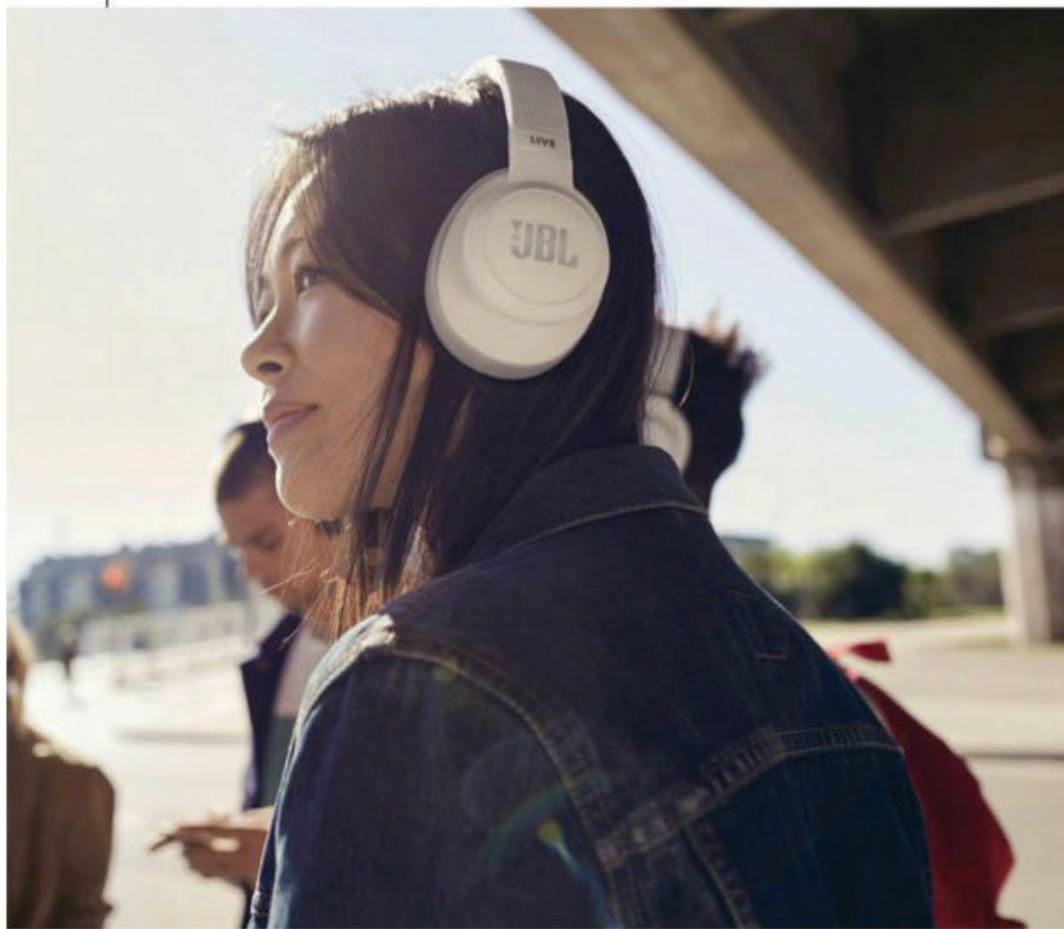
For those that like to travel light, there's the LIVE220BT. These in-ear neckband headphones feature 8mm drivers, weigh just 31g and offer 10 hours of continuous playback from a single charge. Moving up the range, the on-ear LIVE400BT headphones boast 24 hours of battery life and 40mm drivers, weigh 185.8g and will

be perfect for those seeking an adaptable pair of headphones that are suitable for use both at home and on the move. Both of these headphones feature JBL's Ambient Aware and Talk Thru modes. Activated with a single button press, these boost ambient noise and lower music volume, respectively, so you can hear what's going on around you (if you're waiting for a train, for instance) and, if necessary, reply to people without deafening them!

If, on the other hand, you're going to be doing most of your listening at home (or don't mind carrying a bulkier pair of cans around) then take a look at the LIVE500BT and LIVE650BTNC headphones.

Weighing in at 231.6g and 260g, respectively, both are over-ear models for maximum exclusion of external noise and fuller bass response, both have buttons on the earcups for making and receiving calls, and both offer 30 hours' playback from a single two-hour charge. The key difference between the two is that the 500's have 50mm drivers, while the 650's only have 40mm drivers but also offer active noise cancellation to block out external noise.

All four models, of course, offer the high-quality sound for which JBL is known. So if you need some new wireless headphones, perhaps it's time to LIVE a little?



Key Features

- Compatible with Google Assistant and Amazon Alexa
- Available in a range of styles to suit different user needs
- Ambient Aware function for when you need to keep in touch with your surroundings
- Active Noise Cancellation (LIVE650BTNC only)

JBL LIVE range
£69.99 to £179.99



TO DISCOVER MORE, VISIT UK.JBL.COM/HEADPHONES



iOS • ANDROID • SONOS • CHROMECAST



Streaming, reinvented for classical music

Your favourite classical music app. Anywhere, anytime.

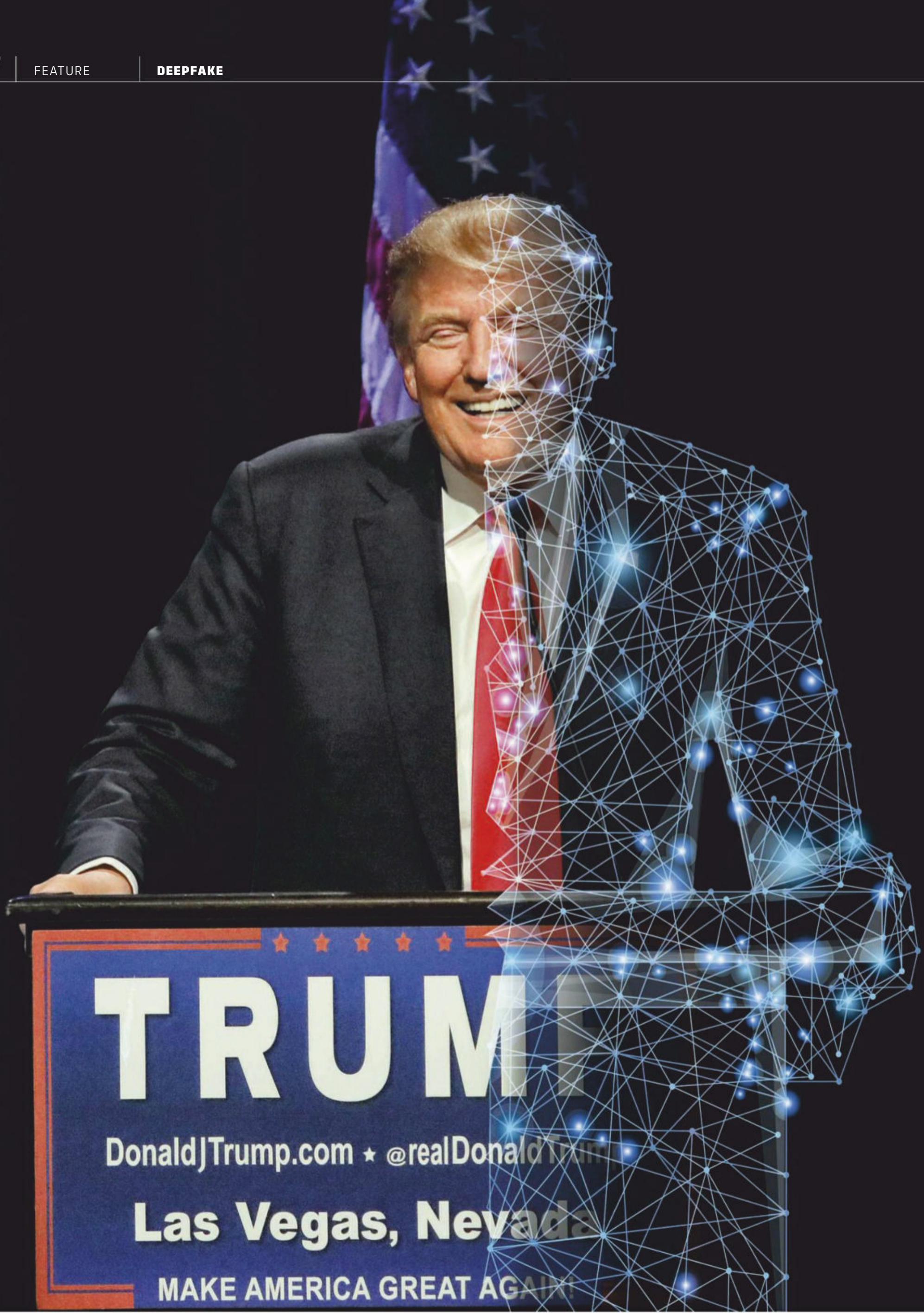
Best search

Browse over 2 million tracks by composer, performer, genre, period, instrument or even mood.

Expert curation

Discover playlists recommended by acclaimed performers and experts in lossless audio.

Try it for free at idagio.com



TRUMP

DonaldJTrump.com • @realDonaldTrump

Las Vegas, Nevada

MAKE AMERICA GREAT AGAIN!

THE FIGHT AGAINST DEEP FAKE



NEXT-GENERATION AI IS THREATENING TO TAKE
INTERNET FAKERY TO A DANGEROUS NEW LEVEL. WE
MEET THE EXPERTS WHO ARE FIGHTING BACK

by ANDY RIDGWAY

It's 2 November 2020, the eve of the US presidential election, and a secretly recorded video is all over the news. Donald Trump has been filmed saying that he's been "talking to the Russians. Believe me, I've been doing some incredible spying. Really incredible". Despite Trump's protests that he never said those words, it proves to have a major effect on voters, and the rival Democratic candidate wins the election.

But Trump was telling the truth – he didn't say those words. The footage of him was generated by 'deepfake' technology, which uses sophisticated artificial intelligence (AI) to create video and audio that impersonates real people. The technology is in use already and, if left unchecked, could lead us to start doubting everything we watch and hear online.

But it's not just on the internet that the effects of deepfake could be felt. Suppose a criminal 'deepfaked' your

sister's voice and called you, asking you to transfer money because "I'm in trouble and desperately need your help". Would you fall for it?

Thankfully, experts are becoming increasingly aware of the dangers that deepfake poses. And they're beginning to fight back by harnessing the very techniques that make this technology so convincing.

GOING DEEPER

Deepfake can be used for all kinds of trickery, but it's most commonly used for 'face swaps', where one person's face is superimposed onto another. In one demonstration, the filmmaker Jordan Peele's mouth is transferred onto Barack Obama's face, so Peele can get the former US president to say whatever he likes (see bit.ly/peeple_obama).

Deeptrace, an Amsterdam-based company that's been set up to tackle the threat of deepfake, estimates that there are around 10,000 deepfake videos circulating online. Over 8,000 of these are pornographic clips, where a celebrity's

"[EXPERTS ESTIMATE] THAT THERE ARE AROUND 10,000 DEEPFAKE VIDEOS CIRCULATING ONLINE"

BELOW

Filmmaker Jordan Peele (right) puts words in Barack Obama's mouth



HOW MUCH OF THE INTERNET IS FAKE?

face is superimposed onto a porn star's body. Experts are predicting that it's only a matter of time before a fake video emerges of a politician purportedly saying or doing something that changes the course of an election.

The word 'deepfake' is a portmanteau of 'deep learning' and 'fake'. Deep learning is a form of AI where algorithms inspired by the human brain, known as neural networks, learn new skills by processing vast amounts of data. At the heart of a deepfake is a form of deep learning known as 'generative adversarial networks', or GANs. Here, two neural networks work against each other to create realistic video and sound. One network, the generator, is the creative bit. This is fed reams of data, such as images of a celebrity's face, and tasked with generating the same face artificially. Another network, the discriminator, is tasked with spotting whether the image it receives from the generator is fake, feeding back what's wrong with it. When the discriminator rejects a video, the generator tries again. This back and forth continues until the generator produces something that's almost indistinguishable from reality. A deepfake is born.

One of the reasons that this technique is so effective is because the discriminator is capable of something that the human mind is not: mathematically describing what's wrong with an image or sound. "I could notice that the generator gets shadows wrong in the images it creates, but I can't describe that mathematically," says Carter Huffman, chief technical officer at Modulate, a company using this technology to develop artificial voices. "I can't just write down a formula for that. But the discriminator can suggest corrections that we don't have the ability to write down a formula for."

The technology behind deepfakes isn't just put to nefarious uses, however. The team at Modulate foresees its artificial voices being used as 'voice skins' in gaming, enabling gamers to take on new personas. Meanwhile, teams at universities around the world are developing these techniques for other positive purposes (see box, p68). But algorithms for creating deepfakes have found their way onto online repositories where computer code is shared and these can be exploited by amateur developers. All it takes is a laptop with a graphics processing unit and a little software knowhow, to create a believable fake. While some of the efforts have been innocent fun, the explosion of celebrity face-swap porn demonstrates the potential for misuse – and that misuse is predicted to spread into other realms soon.

"We've always been able to manipulate video," says Prof Hany Farid, an expert in digital forensics at University of California, Berkeley. "Hollywood studios have done it, individuals acting covertly on behalf of governments have done it. Now imagine a landscape where the average Reddit user can make fake videos of Theresa May – that's a little worrisome."

FIGHTING BACK

Farid is so concerned about a world leader being deepfaked that he and his team are developing a system for recognising deepfakes of specific politicians. They're currently using automated software to analyse the head and face movements of a handful of leaders around the world, including Donald Trump, Theresa May, and others. The system is still in development, but Farid believes it will be ready to use within a year.



DEEFAKE IS JUST THE TIP OF AN ICEBERG

There aren't any accurate measures of exactly how much of what's online is fake (content that's deliberately misleading or inaccurate, rather than honest mistakes). Part of the problem is that a lot of fake stories creep past the algorithms designed to spot them – recent studies suggest these algorithms are only around 75 per cent accurate.

Online fakery takes many forms. While we're most familiar with fake news in politics, there's a growing roster of phoney content, from deepfake videos to 'sockpuppet' accounts created to post positive reviews on consumer websites.

The main problem with fake content isn't necessarily the volume, it's the fact that it propagates like wildfire. A study published in *Science* last year found that fake stories are shared far more widely on Twitter than real ones. The reason? Fake news tends to be seen as more exciting and interesting than the truth. All of this has led to concerns that we'll soon reach a point that's been termed 'the inversion', where our judgment becomes so skewed that we begin to interpret real news as fake and fake news as real.

There are efforts to fight back, though. The UK fact-checking charity Full Fact has developed a system called 'Trends' that looks at the rise and fall of false claims' online popularity. It's revealing some interesting patterns, with claims almost fizzling out and then re-appearing again. By identifying false claims that have risen in prominence, it helps the Full Fact team to prioritise where they should focus their requests for corrections.

• May and Angela Merkel, to identify unique patterns. A suspected fake video of one of these leaders can then be analysed to see whether it matches their real-life movements.

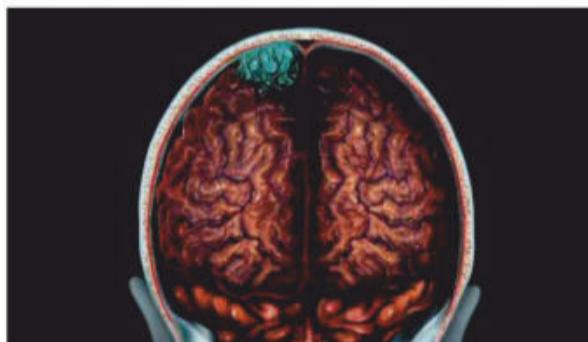
"World leaders tend to have distinct and predictable patterns of facial expressions and head movements," says Farid. "It's difficult for current deepfake systems to mimic these because they're focused on trying to make sure that each frame of the video looks believable." When the individual frames come together, there's no guarantee that the person will move in their own nuanced way, and it's this peculiarity that Farid will use to spot deepfakes. He's hoping to have his system operational by the end of 2019 – ahead of the 2020 US presidential elections.

Meanwhile, in Amsterdam, Deeptrace is developing a deepfake detection system that effectively turns the technology on itself. It uses a powerful discriminator algorithm (the aspect of deepfake technology that spots when a video or image has strayed from reality) to look for fakes. Whereas the discriminator algorithms used to generate deepfakes are designed to create videos that fool the average human, Deeptrace is aiming to create a discriminator that's



RIGHT Deepfake tech enabled the BBC's Matthew Amroliwala to become a polyglot

THE UPSIDE OF DEEFAKE: IT'S NOT ALL BAD NEWS?



SPOTTING BRAIN TUMOURS

It's widely predicted that AI, and deep learning in particular, will transform medical diagnoses, through being trained to spot everything from breast cancer to Alzheimer's disease in scans. The trouble is, the AI software needs a lot of data to hone its detection skills. Deepfake technology can help by generating vast numbers of fake scans containing realistic tumours and lesions.



BETTER LIP-SYNCING

What if a film could be shot in one language and then translated into others with perfect lip syncing? Last year, BBC Click created a video showing presenter Matthew Amroliwala delivering the news in Spanish, Mandarin and Hindi, despite the fact that he only speaks English (bit.ly/language_news). The same tech has enabled David Beckham to speak nine languages (bit.ly/Beckham_malaria).



RESURRECTING THE DEAD

The British Library has audio recordings of many historical figures, including Harry Houdini. At the University of Washington, an AI technique has been developed that can create realistic mouth movements from audio files and graft them onto a face. Soon this technology may allow us to recreate historical figures by combining audio recordings with old photos and videos.

"THE EXPLOSION OF CELEBRITY FACE-SWAP PORN DEMONSTRATES THE POTENTIAL FOR MISUSE"

BBC X2, GETTY IMAGES X2, UNIVERSITY OF CALIFORNIA BERKELEY, MALARIA NO MORE UK

sophisticated enough to spot incredibly subtle flaws in deepfakes, giving them a one-up on the people making them.

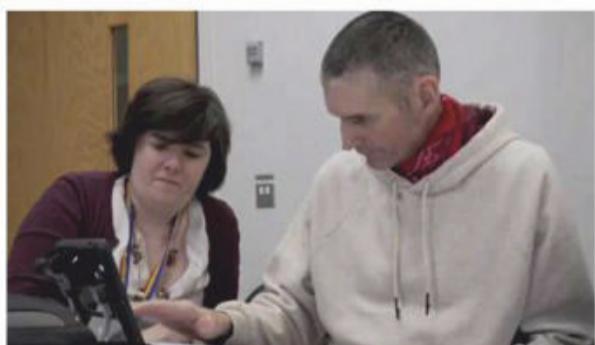
The Deeptrace team is currently feeding its discriminator thousands of fake videos to hone the system. In much the same way as the original technology is not programmed how to generate a realistic face, Deeptrace's discriminator learns how to spot the fakes from the data it's fed. "Any algorithm that's used to manipulate images leaves behind geometric patterns on them," says Giorgio Patrini, chief executive officer of Deeptrace. "These artefacts would not appear in genuine images from a camera and are often not visible to the human eye."

These patterns might not only reveal if a video is a deepfake, but also how it was created. "Families of algorithms will leave different traces, so sometimes we might get some information about the generator algorithm that was used," says Patrini. "Tracing the algorithm could help us to identify, for example, how a human face was manipulated – was it just the facial expression or the person's entire appearance and identity?"

Patrini and his business partner Francesco Cavalli see the main market for their technology initially being media companies. "Journalists would like proof of whether a video is real or fake," says Patrini. But they see lots more opportunities on the horizon. "As soon as people realise that they can deepfake things like phone calls and video conferencing technology, it opens up a world of misuse," says Patrini.

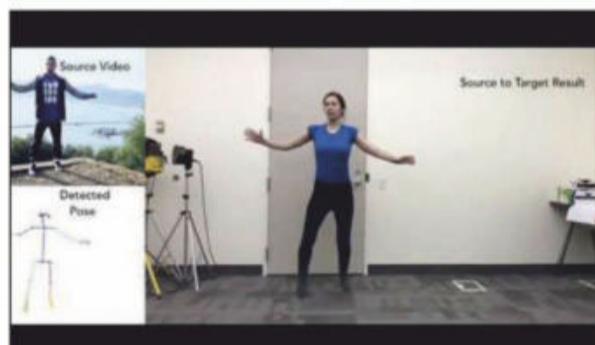
At Modulate, the team has recognised the risk of misinformation and are embedding sonic 'watermarks' in the sound files they create so their work can be traced back to them, hopefully acting as a disincentive to anyone thinking of misusing the technology. "The watermarks are slight tweaks to some of the sound frequencies, in ways that you won't be able to hear," says Huffman. Modulate hopes to form a coalition with other AI speech-generation companies and establish a self-policing system where anyone will be able to upload sound files to a dedicated website to find out whether or not they carry a company watermark.

But even those fighting deepfakes recognise that their detection systems are only part of the solution. Even if a deepfake video can be spotted as a fake, it can still be spread across social networks in a matter of minutes before anyone has had the chance to verify it, potentially changing the course of elections or destroying careers. So perhaps the emergence of deepfake calls for a shift in our mindset, where we recognise that seeing is no longer always believing. "We really need to rewire ourselves to stop believing that a video is the truth," says Patrini. "But it will take effort in education, and potentially catastrophic events in the news, to finally get there." SF



GIVING VOICE TO THE SILENT

Speech synthesisers used by people who've lost their voices to medical conditions such as oral cancer and motor neurone disease typically sound robotic. But US company VocaliD uses deepfake technology to generate artificial voices that match a person's sex and personality. VocaliD says it is also creating measures to ensure the technology it's developing isn't misused.



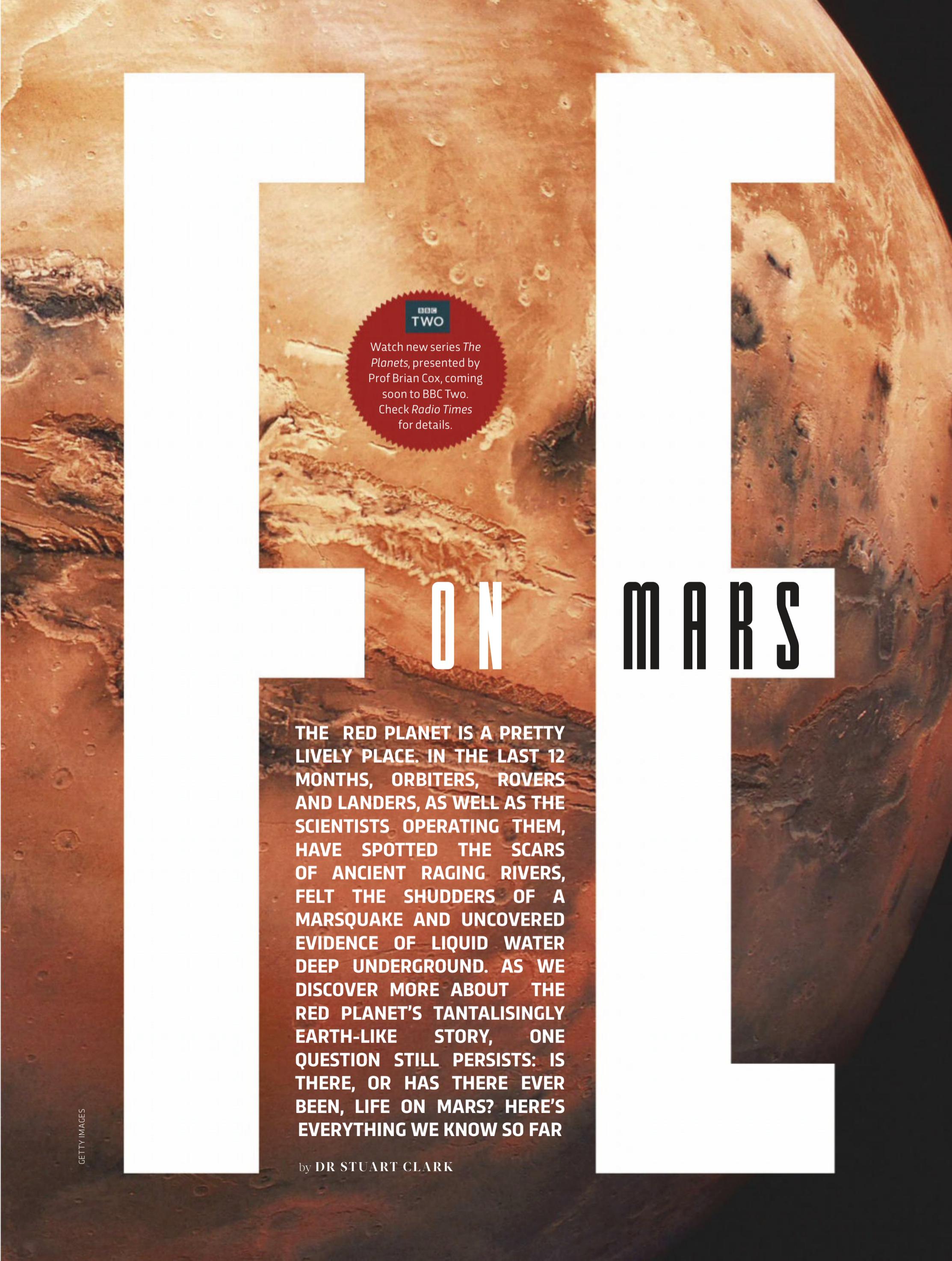
CUTTING THE COST OF CGI

It's not just faces that can be deepfaked: bodies can be, too. Scientists at University of California, Berkeley have developed a system that maps body movements from one video to another, making amateur dancers move like pros (bit.ly/fake_dance). It could be a cheaper alternative to the motion-capture technology commonly used to animate film characters such as Gollum and King Kong.

by ANDY RIDGWAY

Andy is a freelance science writer and science communication lecturer based in Bristol.





THE RED PLANET IS A PRETTY LIVELY PLACE. IN THE LAST 12 MONTHS, ORBITERS, ROVERS AND LANDERS, AS WELL AS THE SCIENTISTS OPERATING THEM, HAVE SPOTTED THE SCARS OF ANCIENT RAGING RIVERS, FELT THE SHUDDERS OF A MARSQUAKE AND UNCOVERED EVIDENCE OF LIQUID WATER DEEP UNDERGROUND. AS WE DISCOVER MORE ABOUT THE RED PLANET'S TANTALISINGLY EARTH-LIKE STORY, ONE QUESTION STILL PERSISTS: IS THERE, OR HAS THERE EVER BEEN, LIFE ON MARS? HERE'S EVERYTHING WE KNOW SO FAR

by DR STUART CLARK

BBC
TWO

Watch new series *The Planets*, presented by Prof Brian Cox, coming soon to BBC Two. Check *Radio Times* for details.

ON MARS

A GASSY ENIGMA

ARE MARTIAN MICROBES BELCHING GAS INTO THE PLANET'S ATMOSPHERE?

In March 2004, ESA's Mars Express mission confirmed that methane gas was present in the Martian atmosphere. The amount of methane was small but its discovery was extraordinary because on Earth, although some methane in the atmosphere comes from volcanoes, most of it is produced by living organisms.

Methane only survives in the Martian atmosphere for a few hundred years, meaning that whatever was producing it was (geologically speaking) recent. Although the volcanic explanation would be fascinating because Mars was thought to be geologically dead, the biological origin is what grabbed people's attention.

The methane seen by Mars Express was concentrated in certain regions and quickly dispersed to levels that could no longer be detected. Then, a decade later, the methane returned.

This time it was detected by NASA's Mars Curiosity rover, which had landed in Gale Crater in 2012. Using its onboard Sample Analysis at Mars (SAM) instrument suite, the rover took a dozen readings over a 20-month period, mostly revealing extremely low levels of the gas. However, in late 2013 and early 2014, methane levels rose sharply by a factor of 10.

"At this point we don't know the origin of this methane," said NASA's Danny Glavin, a participating scientist in the Curiosity mission, at the time. The same remains true to this day.

Most recently, a re-analysis of Mars Express data has shown that it too detected methane in Gale Crater in June 2013. However, ESA's follow-on mission to look specifically for methane, the Trace Gas Orbiter, has not yet seen any traces at all, despite looking with sensitivities between 10 and 100 times

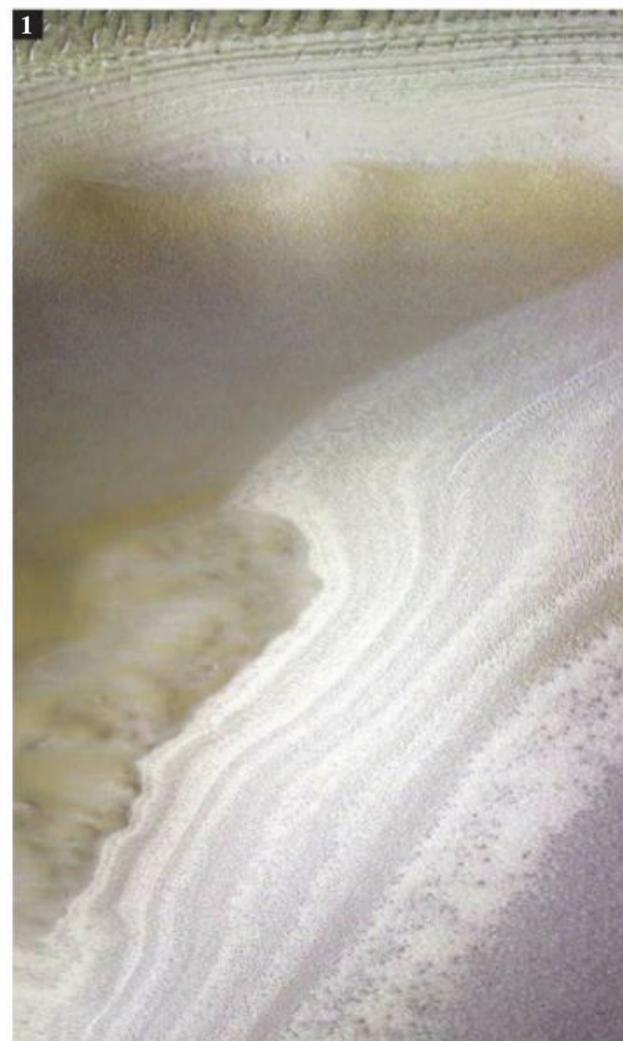
higher than the previous positive detections.

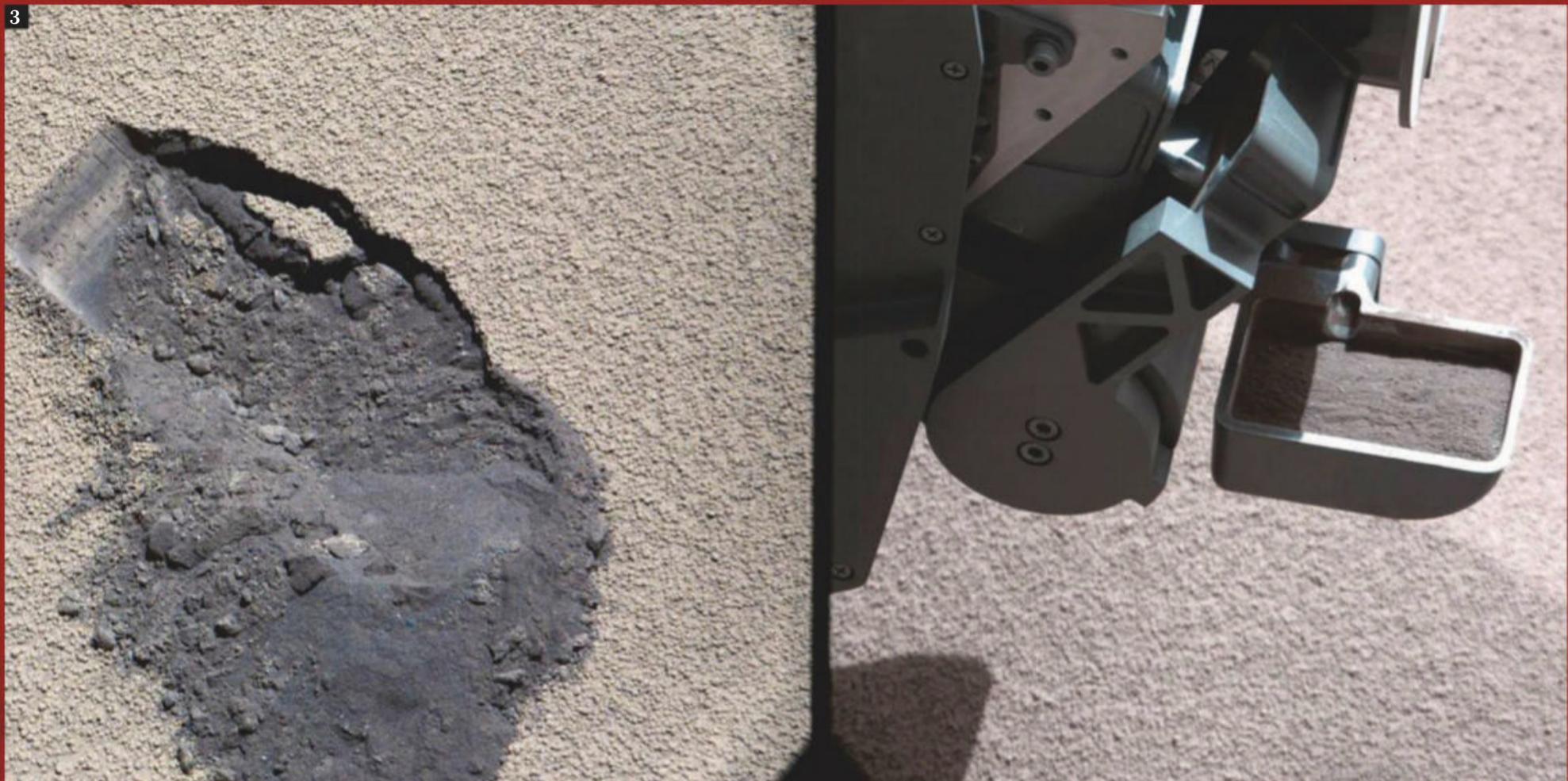
In 2020, the second part of the ExoMars mission, containing a lander and rover, will arrive at Mars and continue the search. "The Rosalind Franklin rover itself won't look specifically for atmospheric methane [but] the ExoMars landing module, named Kazachok, will have several different atmospheric spectrometers on board, so these will also investigate the local chemical composition of the Martian atmosphere," said Abbie Hutty, ExoMars delivery manager and structure supplier operations manager at Airbus Defence and Space.

1 Snapshot of Mars's south pole, taken by ExoMars's Trace Gas Orbiter

2 The Mars Curiosity rover detected methane at Gale Crater, as photographed here

3 The intrepid rover collecting soil samples from the surface of Mars





SAMPLE RETURN

THE ONLY WAY TO BE CERTAIN IS TO BRING SOMETHING BACK

In the search for life on Mars, many researchers believe that there is only one way to make real progress: bring Mars rocks back to Earth. According to Prof Monica Grady, a planetary and space scientist at The Open University, the “plan to bring back rocks from Mars is our best bet for finding clues to past life.” Last year, ESA and NASA signed a memorandum of understanding that pledges the agencies to work together to design a series of missions that will bring Mars rocks back to Earth. “Returning Martian samples is a huge challenge that will require multiple missions, each one successively more complex than the one before,” said David Parker, ESA’s director of human and robotic exploration. NASA’s 2020 rover will be a step towards sample return because it will cache interesting samples in up to 31 canisters that will be left on the Martian surface. A second mission would then retrieve those canisters and place them in a Martian ascent vehicle, which would boost them into orbit. A third mission from Earth would rendezvous with this vehicle in Mars orbit and bring it back to Earth. “A Mars sample return mission is a tantalising but achievable vision that lies at the intersection of many good reasons to explore space,” says Parker.

European science ministers will meet later this year to decide whether to fund the necessary sample return missions.

MAKING A SPLASH ON THE RED PLANET

LIQUID WATER IS LURKING BENEATH MARS'S SURFACE. HERE'S HOW WE'LL STUDY IT

Planetary geologists have long wondered what happened to the Martian water. Either it escaped into space or it seeped into the ground. If it's in the ground then there should be great underground lakes of water or buried ice sheets. In the mid-2000s, both ESA and NASA sent spacecraft to Mars with radars capable of searching for these deposits.

ESA's MARSIS instrument and NASA's SHARAD are complementary ground-penetrating radar that gradually unveiled the truth.

In November 2016, SHARAD found a large deposit of subsurface ice in the Utopia Planitia region of Mars. This is a large expanse, some 3,300 kilometres across, and the volume of water contained in the ice was

estimated to be enough to fill Lake Superior, the largest of the Great Lakes in North America. The top of the ice sheet is covered by between 1 to 10 metres of Martian dust, explaining why it has never shown up in optical images of the surface. "This deposit is probably more accessible than

most water ice on Mars, because it is at a relatively low latitude and it lies in a flat, smooth area where landing a spacecraft would be easier than at some of the other areas with buried ice," says Jack Holt of the University of Texas, a SHARAD co-investigator. This means that it could one day help to sustain astronauts by being the Martian equivalent of a frozen water spring. It may also contain clues to whether life started on Mars or not.

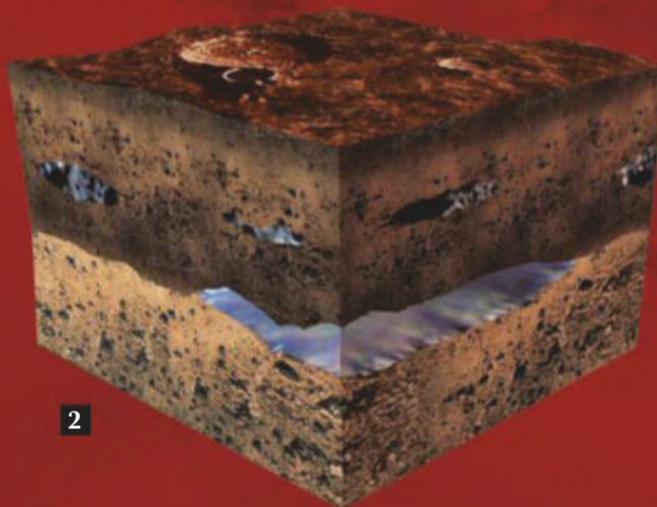
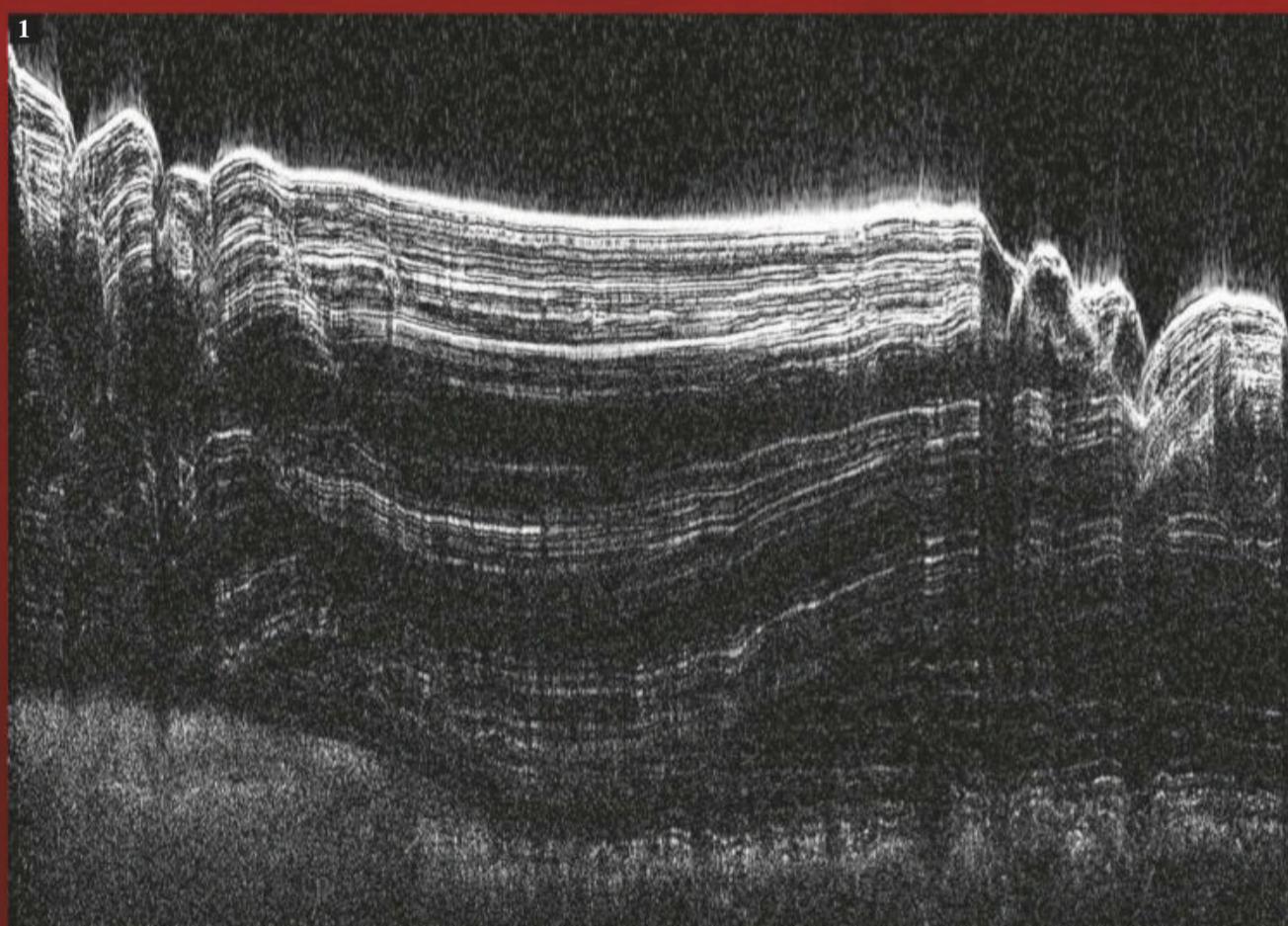
In July 2018, Mars Express's MARSIS instrument found evidence for a lake of water buried near the planet's south pole. The radar reflections show that the underground lake is more than a kilometre and a half below the surface, and approximately 20 kilometres wide.

"This is just one small study area; it is an exciting prospect to think there could be more of these underground pockets of water elsewhere, yet to be discovered," says Roberto Orosei, principal investigator of the MARSIS experiment.

The discovery is a bit similar to the subglacial lakes of Antarctica on Earth, and forms of microbial life are known to thrive in these environments. Reaching the Martian lake, however, would require serious technology. It's more than a kilometre and a half down and the Rosalind Franklin rover, which boasts the deepest drill ever to go to Mars, is only capable of penetrating two metres below the surface. Don't hold your breath on this one.

1 NASA's SHARAD used ground-penetrating radar to reveal layers of subsurface ice on Mars

2 Artist's impression of water beneath the Martian surface



Rosalind Franklin

AIRBUS eesa



←
ExoMars rover
under
construction in
a clean room

PLANETARY PROTECTION

LIMITING
THE RISK OF
CONTAMINATION

In 1969, American novelist Michael Crichton wrote the bestselling thriller, *The Andromeda Strain*. It told the harrowing story of an outbreak of extraterrestrial microbes that had been brought back to Earth by a returning satellite. But what about contamination the other way – Earth microbes running amok on Mars?

The detection of life on Mars would be one of the greatest scientific discoveries of all time. So the last thing we should

want to do is risk contaminating Mars by sending dirty spacecraft to the surface.

The Committee On Space Research (COSPAR), an international organisation founded in 1958, sets strict standards to limit biological contamination between planetary bodies. As a result, the major space agencies go to extraordinary lengths to sterilise their spacecraft before sending them to areas on Mars that may be habitable.

Sterilising a spacecraft is no easy job. The first Mars landers were NASA's Viking 1 and 2. They needed to be well sterilised because they were looking for Martian microbes. Built in the 1970s, the surfaces of the spacecraft were first cleaned thoroughly to significantly reduce the 'bio-burden'. Then, they were placed in an oven and heated to 112°C for 30 hours. NASA estimated that the baking reduced the remaining bacteria by a factor of a million.

ESA's Rosalind Franklin rover must adhere to similar standards. "We have to make sure that during the actual build of the rover, which is almost entirely done by humans, that those humans don't contaminate the rover with particles of skin, hair, or greases from their skin. This means that the technicians have to do so in a specially built 'clean room', which is isolated from the normal working environment, and that they must wear full body protective gear," says Huttley.

Planetary protection will be a major concern when returning rocks from Mars for study in Earth's laboratories. The COSPAR guidelines call for the most stringent safeguard for such Category V missions, as they are known.

"WE HAVE TO MAKE SURE THAT HUMANS DON'T CONTAMINATE THE ROVER WITH PARTICLES OF SKIN, HAIR, OR GREASES FROM THEIR SKIN"



The European Space Agency's Mars rover undergoing tests

HAVE WE ALREADY FOUND MARTIAN LIFE?

SOME SCIENTISTS THINK THAT HINTS OF LIFE WERE DISCOVERED BACK IN THE 1970s

Considering all the talk surrounding life on Mars and all the many spacecraft and landers that have gone to the Red Planet since the 1970s, it may seem surprising that only the first two carried equipment to look for life. There were four biological experiments on the Viking spacecraft. Of these, only one returned positive results.

The Labeled Release experiment was simple. It took a sample of Martian soil and introduced some liquid nutrients. Those nutrients had been 'labelled' with a radioactive carbon isotope. If bacteria were present in the soil, they would metabolise the nutrient and expel the carbon isotope, which would be detected by the instrument. When the experiment was run on both landers, both returned positive results. The second part was to sterilise the soil and see if that made the signal go away. It did, no radioactive gas was detected that time.

"Right then and there we satisfied the pre-mission, agreed upon criteria for life. We could have said we've detected life, hung our hats up, grabbed a bottle of

champagne and celebrated. That was not to be," said Gilbert Levin, who was the experiment's principal investigator. Instead, the researchers wondered why none of the other experiments had returned positive results, and declared that the Viking experiments were inconclusive but probably hadn't found life. Over the years, researchers have proposed various non-biological reactions that could reproduce some aspects of the experiment's results. Levin, however, has continued to champion the biological interpretation, claiming that no chemical has been able to totally mimic the results.

In 2012, Joseph Miller, a neurobiologist at the University of Southern California and a former NASA space shuttle project director, and mathematician Giorgio Bianchiardi, from Italy's University of Siena, re-analysed the Viking data. Using maths, they showed the data was more consistent with biological activity than simple chemistry.

The only way out of the impasse is to look for life again, which is where ESA's ExoMars mission comes in. "The Rosalind Franklin rover's mission is to detect life, either past or present, on the Martian surface," says Huttley.

After all this time, maybe soon we will have the answer about whether there is life on Mars. SF

by DR STUART CLARK

(@DrStuClark)

Stuart is an astronomy writer. His latest book, The Search For Earth's Twin (£12.99, Quercus) is out now.

Welcome to our 2019 reader survey! You will probably have noticed that we've recently changed the name of *BBC Focus* to *BBC Science Focus*. We're really excited by this evolution and the other modifications we've made, all using your feedback to previous research – so thank you! This is your chance to tell us what you think about the new-look *BBC Science Focus* and continue to help shape how we move forwards. Please return your completed questionnaire by **13 June 2019** to the Freepost address supplied at the end, or alternatively you can fill it in online at sciencefocus.com/readersurvey UK residents who return a completed questionnaire have the opportunity to enter our prize draw for a chance to **win one of four £100 Amazon vouchers**; please see our T&Cs on p78 for more information. We look forward to hearing from you.



A. MAGAZINE READING BEHAVIOUR

1. How often do you read *BBC Science Focus* magazine? (Previously *BBC Focus*)?

- | | |
|---|----------------------------|
| Always – I subscribe | <input type="checkbox"/> 1 |
| Always – every issue but I don't subscribe | <input type="checkbox"/> 2 |
| Almost always (3 in 4 issues) | <input type="checkbox"/> 3 |
| Quite often (1 or 2 in 4 issues) | <input type="checkbox"/> 4 |
| Occasionally (less than 1 in 4 issues) | <input type="checkbox"/> 5 |
| Not in the last 12 months | <input type="checkbox"/> 6 |
| This is my first issue (go to Q8) | <input type="checkbox"/> 7 |

2. How long have you been reading *BBC Science Focus* magazine for? Please think about the full length of time since you first read *BBC Focus*.

- | | |
|------------------------------------|----------------------------|
| Less than a year (go to Q5) | <input type="checkbox"/> 1 |
| Between 1 and 2 years | <input type="checkbox"/> 2 |
| Between 2 and 5 years | <input type="checkbox"/> 3 |
| Between 5 and 10 years | <input type="checkbox"/> 4 |
| More than 10 years | <input type="checkbox"/> 5 |

3. Compared to a few years ago, are you buying *BBC Science Focus* magazine (previously *BBC Focus*)...?

- | | | | |
|-------------------|----------------------------|----------------------------|----------------------------|
| More often | <input type="checkbox"/> 1 | Same as always | <input type="checkbox"/> 3 |
| Less often | <input type="checkbox"/> 2 | I read someone else's copy | <input type="checkbox"/> 4 |

4. Compared to a year ago, how do you feel about *BBC Science Focus* (previously *BBC Focus*) now?

- | | |
|--|----------------------------|
| The magazine has improved considerably | <input type="checkbox"/> 1 |
| The magazine has improved a little | <input type="checkbox"/> 2 |
| It is more or less the same as a year ago | <input type="checkbox"/> 3 |
| The magazine has got a little worse | <input type="checkbox"/> 4 |
| The magazine has got considerably worse | <input type="checkbox"/> 5 |

5. Thinking about an average issue of *BBC Science Focus* magazine, how many other people read or look at your copy for longer than two minutes?

- | | | | |
|-------------------------------|----------------------------|-------------------|----------------------------|
| Nobody else (go to Q7) | <input type="checkbox"/> 1 | 3-4 people | <input type="checkbox"/> 3 |
| 1-2 people | <input type="checkbox"/> 2 | 5 or more people | <input type="checkbox"/> 4 |

6. And who has read or looked at any of your copies of *BBC Science Focus* (previously *BBC Focus*) for longer than two minutes? Please select all that apply.

- | | |
|----------------------------|----------------------------|
| My partner | <input type="checkbox"/> 1 |
| Friends | <input type="checkbox"/> 2 |
| Colleagues | <input type="checkbox"/> 3 |
| Children aged over 18 | <input type="checkbox"/> 4 |
| Children aged 16-18 | <input type="checkbox"/> 5 |
| Children aged under 16 | <input type="checkbox"/> 6 |
| Other family member | <input type="checkbox"/> 7 |
| Other | |

7. On average, how long do you spend reading an issue of *BBC Science Focus* magazine (previously *BBC Focus*)?

- | | |
|-------------------------------|----------------------------|
| Under 30 minutes | <input type="checkbox"/> 1 |
| Between 30 minutes and 1 hour | <input type="checkbox"/> 2 |
| Between 1 and 2 hours | <input type="checkbox"/> 3 |
| Between 2 and 3 hours | <input type="checkbox"/> 4 |
| Between 3 and 4 hours | <input type="checkbox"/> 5 |
| Between 4 and 5 hours | <input type="checkbox"/> 6 |
| More than 5 hours | <input type="checkbox"/> 7 |

Please go to Q9 if you've been reading for longer than one year.

8. Which of the following encouraged you to try *BBC Science Focus* magazine in the last year? Please select all that apply.

- | | |
|---|-----------------------------|
| I love science | <input type="checkbox"/> 01 |
| I'm newly interested in science | <input type="checkbox"/> 02 |
| It looked like an interesting magazine | <input type="checkbox"/> 03 |
| It looked topical | <input type="checkbox"/> 04 |
| The name of the magazine made it clear what it was about | <input type="checkbox"/> 05 |
| Hadn't seen it before/thought it was new | <input type="checkbox"/> 06 |
| Striking cover/s | <input type="checkbox"/> 07 |
| Was on offer with another magazine | <input type="checkbox"/> 08 |
| Ad on sciencefocus.com website | <input type="checkbox"/> 09 |
| Someone recommended it to me | <input type="checkbox"/> 10 |
| To help me understand how science tackles the big issues facing us today | <input type="checkbox"/> 11 |
| Other | |

9. How often do you read the following magazines?

	1	2	3	4	5	6	7
Always – I subscribe but I don't subscribe	<input type="checkbox"/>						
Always – I subscribe but I don't subscribe	<input type="checkbox"/>						
Almost always	<input type="checkbox"/>						
Quite often	<input type="checkbox"/>						
Occasionally	<input type="checkbox"/>						
Only read one issue	<input type="checkbox"/>						
Never	<input type="checkbox"/>						
BBC Science Focus Collection	<input type="checkbox"/>						
BBC History Magazine	<input type="checkbox"/>						
BBC World Histories	<input type="checkbox"/>						
History Revealed	<input type="checkbox"/>						
BBC Wildlife Magazine	<input type="checkbox"/>						
How It Works	<input type="checkbox"/>						
National Geographic	<input type="checkbox"/>						
New Scientist	<input type="checkbox"/>						

C. MAGAZINE EVALUATION

10. If you know someone interested in science and technology, how likely would you be to recommend *BBC Science Focus* magazine to them?

- | | | | |
|----------------------------|-----------------------------|----------------------------|-----------------------------|
| 0 Not at all likely | <input type="checkbox"/> 01 | 6 | <input type="checkbox"/> 07 |
| 1 | <input type="checkbox"/> 02 | 7 | <input type="checkbox"/> 08 |
| 2 | <input type="checkbox"/> 03 | 8 | <input type="checkbox"/> 09 |
| 3 | <input type="checkbox"/> 04 | 9 | <input type="checkbox"/> 10 |
| 4 | <input type="checkbox"/> 05 | 10 Extremely likely | <input type="checkbox"/> 11 |
| 5 | <input type="checkbox"/> 06 | | |

11. To what extent have you noticed changes made to *BBC Science Focus* magazine?

- | | | | |
|-------------------|----------------------------|------------|----------------------------|
| Very much | <input type="checkbox"/> 1 | Not at all | <input type="checkbox"/> 4 |
| A little | <input type="checkbox"/> 2 | Not sure | <input type="checkbox"/> 5 |
| Not really | <input type="checkbox"/> 3 | | |

12. How much do you agree or disagree with the following statements about the new-look *BBC Science Focus* magazine?

- | | 1 | 2 | 3 | 4 | 5 | 6 | Don't know |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|------------|
| I'm likely to buy more often now | <input type="checkbox"/> | |
| I'm likely to buy less often now | <input type="checkbox"/> | |
| I like the new Reality Check section | <input type="checkbox"/> | |
| I like there being more news | <input type="checkbox"/> | |
| I like there being more Q&A | <input type="checkbox"/> | |
| I like the extended Discoveries section | <input type="checkbox"/> | |
| I miss the Innovations section | <input type="checkbox"/> | |
| The design is cleaner | <input type="checkbox"/> | |
| It's become more serious | <input type="checkbox"/> | |
| It stands out better on the newsstand | <input type="checkbox"/> | |
| The name suits the content better | <input type="checkbox"/> | |

13. How much did you enjoy this issue of *BBC Science Focus* magazine?

- | | |
|--|----------------------------|
| Very much | <input type="checkbox"/> 1 |
| Quite a lot | <input type="checkbox"/> 2 |
| Not very much | <input type="checkbox"/> 3 |
| Not at all | <input type="checkbox"/> 4 |
| Haven't read this issue yet (Go to Q15) | <input type="checkbox"/> 5 |

14. Listed below are all the articles in this issue of *BBC Science Focus* magazine. For each item, please select the column that comes closest to your opinion.

	Very interesting	Quite interesting	Not that interesting	Not at all interesting	Did not read
	1	2	3	4	5
Eye opener – p8	<input type="checkbox"/>				
Conversation – p10	<input type="checkbox"/>				
Discoveries – p13-25	<input type="checkbox"/>				
Reality Check – p28	<input type="checkbox"/>				
The Sharpest Tools – p36	<input type="checkbox"/>				
No More Pain – p42	<input type="checkbox"/>				
Angela Saini interview – p48	<input type="checkbox"/>				
Michael Mosley – p55	<input type="checkbox"/>				
Aleks Krotoski – p56	<input type="checkbox"/>				
The Fight Against Deepfake – p64	<input type="checkbox"/>				
Life On Mars – p70	<input type="checkbox"/>				
Q&A – p79-87	<input type="checkbox"/>				
Radar – p89-96	<input type="checkbox"/>				
Crossword – p97					

READER SURVEY



17. Do you have any other comments you'd like to make about BBC Science Focus?

.....
.....
.....

18. On average, how often do you visit the BBC Science Focus website (sciencefocus.com)?

- 1 More than once a day
- 2 Once a day
- 3 About 2-3 times a week
- 4 Once a week
- 5 Once every couple of weeks
- 6 Once a month
- 7 Every 2-3 months
- 8 Less often
- 9 Never visited it

19. On average, how often do you listen to the BBC Science Focus podcast?

- 1 Every week
- 2 Regularly (at least once a month)
- 3 Occasionally (once every few months)
- 4 Never, but I'm aware of it
- 5 Never – I wasn't aware of it

20. Which, if any, of the following resources or services would you consider buying from BBC Science Focus magazine? Please select all that apply.

- 01 Online tutorials
 - 02 Online courses
 - 03 Printed tutorials
 - 04 Printed courses
 - 05 Video guides
 - 06 Live talks/lectures
 - 07 Expert essays
 - 08 Reading lists
 - 09 Further research
 - 10 Programme recommendations
 - 11 Science puzzles special edition
 - 12 BBC Science Focus magazine for kids
 - 13 Film screenings with expert round table
 - 14 Science book club
 - 15 Travel tours
 - Other (please specify).....
-

C. SCIENCE INTERESTS & ABOUT YOU

21. Which of the following best describes why you read BBC Science Focus magazine? Please select one main reason and as many secondary reasons as apply.

- | | Main reason | Secondary reasons |
|---|--------------------------|--------------------------|
| 1 | 2 | |
| I love science | <input type="checkbox"/> | <input type="checkbox"/> |
| I love technology | <input type="checkbox"/> | <input type="checkbox"/> |
| To stay up to date on discoveries and innovations | <input type="checkbox"/> | <input type="checkbox"/> |
| To learn/educate myself | <input type="checkbox"/> | <input type="checkbox"/> |
| For entertainment | <input type="checkbox"/> | <input type="checkbox"/> |
| For a connection to the world of science | <input type="checkbox"/> | <input type="checkbox"/> |
| As a source of general knowledge | <input type="checkbox"/> | <input type="checkbox"/> |

22. How much do you agree or disagree with the following statements?

- | | Agree strongly | Agree slightly | Neutral | Disagree slightly | Disagree strongly |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 1 | <input type="checkbox"/> |
| I prefer to understand a topic in depth | <input type="checkbox"/> |
| I prefer to know a little bit about a broad range of topics | <input type="checkbox"/> |
| General knowledge is important to me | <input type="checkbox"/> |
| I'm naturally curious | <input type="checkbox"/> |
| I count science among my hobbies | <input type="checkbox"/> |
| I have a specific interest in certain scientific topics/s | <input type="checkbox"/> |
| I'm interested in all scientific topics | <input type="checkbox"/> |

23. Which of the following are you interested in, or have you done in the last 12 months?

- | | Interested in last 12 months | Done in the last 12 months | Neither |
|---|------------------------------|----------------------------|--------------------------|
| Attending a science/tech-related talk or lecture | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Attending a science/tech-related event or festival | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Going to a science/tech museum or exhibition | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Going on a science-related holiday. For example, to see the Northern Lights | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Visiting a place of scientific interest. For example, a National Park/conservation area | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

24. In general, how important are environmental considerations in your day-to-day purchase decisions?

- 1 Very important
- 2 Quite important
- 3 Neutral
- 4 Not that important
- 5 Not at all important

25. Subscriber copies of BBC Science Focus magazine are currently sent out in plastic wrap. Are you aware that the plastic wrap used is recyclable at big supermarkets and at the kerbside in some areas?

- 1 Yes
- 2 No

26. How important are environmental concerns around plastic packaging when considering whether to take out/renew a magazine subscription?

- 1 Very important
- 2 Quite important
- 3 Neutral
- 4 Not that important
- 5 Not at all important

27. What is your current employment status?

- 1 Employed full-time
- 2 Employed part-time
- 3 Studying full-time
- 4 Studying part-time
- 5 Retired
- 6 Not working/unable to work

28. Which of the following best describes the main wage earner's occupation in your household? If retired, please tick the box describing your/their former occupation.

- 1 High managerial, administrative or professional
- 2 Intermediate managerial, administrative or professional
- 3 Supervisory, clerical and junior managerial, administrative or professional
- 4 Skilled manual
- 5 Semi or unskilled manual
- 6 Unemployed
- 7 Student

29. What is your household income before tax?

- 1 Under £20,000
- 2 £20,000-£29,999
- 3 £30,000-£39,999
- 4 £40,000-£49,999
- 5 £50,000-£69,999
- 6 £70,000-£99,999
- 7 £100,000-£149,999
- 8 Over £150,000

30. If you have a child/children, which age group/s do they fit into? Please select all that apply.

- | | Under 2 | 2-5 | 6-11 | 12-15 | 16+ living at home | 16+ flown the nest | Don't have any children |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 1 | <input type="checkbox"/> |
| 2 | <input type="checkbox"/> |
| 3 | <input type="checkbox"/> |
| 4 | <input type="checkbox"/> |

31. Is your home?

- 1 Mortgaged
- 2 Owned outright
- 3 Rented
- 4 Other

32. Are you?

- 1 Male
- 2 Female
- 3 Other
- 4

33. Which age group are you in?

- 1 Under 16*
- 2 16-24
- 3 25-34
- 4 35-44
- 5 45-54
- 6 55-64
- 7 65+

*Unfortunately the prize draw is only open to adults aged 16+

Thank you for taking the time to complete this questionnaire!

If you'd like to be included in our free prize draw for a chance to win one of four Amazon vouchers worth £100, please fill in your name and email address or telephone number clearly in the spaces below.

Name _____

Phone _____

Email _____

Please return your questionnaire by 13 June 2019 to:

FREEPPOST DATAGEMS MARKET RESEARCH

Immediate Media Co (Publishers of BBC Science Focus) would like to keep you informed of newsletters, special offers and promotions via email. You may unsubscribe from these messages at any time. Please tick this box if you'd like to receive these from us

IMMEDIATE MEDIA COMPANY LIMITED PRIZE DRAW TERMS AND CONDITIONS

The promoter is Immediate Media Company. The promotion is open to all residents of the UK, including the Channel Islands and the Isle of Man, aged 16 years or older, except the Promoter's employees or contractors and anyone connected with the promotion or their direct family members. The closing date for entries is 13 June 2019. By entering the promotion, the participants agree:

- (a) to be bound by these terms and conditions;
- (b) that their surname and county of residence may be released if they win a prize; and
- (c) that should they win the promotion, their name and likeness may be used by the Promoter for pre-arranged promotional purposes.

Entrants should enter by completing the survey. Survey completions received after the closing date of the promotion will not be considered. Only one entry will be permitted per person. Bulk entries made by third parties will not be permitted. The winning entrants will be drawn at random from all the completed survey entries after the closing date. The Promoter's decision as to the winners is final and no correspondence relating to the promotion will be entered. The winners will be notified within 28 days of the close of the promotion by email or phone.

There will be four overall prize winners, each winning 1x £100 Amazon voucher. There are no cash alternatives, vouchers or refunds available. The prize is non-transferable, non-refundable and subject to availability. The Promoter reserves the right to substitute the prize with one of the same or greater value.

The names of the winners can be made available by sending a SAE to BBC Science Focus Magazine reader survey, Immediate Media Co, Tower House, Fairfax St, Bristol, BS1 3BN within two months of the closing date of the promotion. The Promoter reserves the right to amend these terms and conditions or to cancel, alter or amend the promotion at any stage, if deemed necessary in its opinion, or if circumstances arise outside of its control. The Promoter does not accept any responsibility for lost, delayed or fraudulent entries. If any winner is unable to be contacted within 28 days of the promotion's closing date, the Promoter reserves the right to offer the prize to a runner up, or to re-offer the prize in any future promotion. The Promoter excludes liability to the full extent permitted by law for any loss, damage or injury occurring to the participant arising from his or her entry into the promotion or occurring to the winner arising from his or her acceptance of a prize. The promotion is subject to the laws of England. The Promoter will use entrants' personal details in accordance with the Immediate Privacy Policy (www.immediatemedia.co.uk/privacy-policy).

ALL YOUR QUESTIONS ANSWERED

GETTY IMAGES

THIS ISSUE'S EXPERTS

DR ALASTAIR GUNN
Astronomer,
astrophysicist

ALEX FRANKLIN-CHEUNG
Environment/
climate expert

DR PETER J BENTLEY
Computer
scientist, author

PROF ALICE GREGORY
Psychologist,
sleep expert

DR HILARY GUITE
Former GP,
science writer

CHARLOTTE CORNEY
Zoo director,
conservationist

DR HELEN SCALES
Oceans expert,
science writer

DR CHRISTIAN JARRETT
Neuroscientist,
science writer

DR EMMA DAVIES
Chemistry expert,
science writer

LUIS VILLAZON
Science/tech
writer

JULES HOWARD
Zoologist,
science writer

PROF ROBERT MATTHEWS
Physicist,
science writer



JUDITH ROBINSON

WHY CAN BABIES CRY FOR HOURS, BUT ONE FOOTBALL MATCH CAN LEAVE A FAN HOARSE FOR DAYS?

Crying is an important behaviour for babies to make sure that they get prompt attention from their parents when they need something. Newborn babies cry for an average of 6.7 hours per day, something that would make an adult become hoarse, lose their voice and eventually develop growths ('nodules') on their vocal cords. Infants have so much endurance because their vocal cords don't have stiffening ligaments yet, and are packed with hyaluronic acid, which makes them much more elastic and shock-absorbing. A side effect of these adaptations is that babies are unable to accurately articulate sounds, which goes some way to explaining all their babbling. *LV*



ROBERT LUCAS, WEST MALLING

IS THERE A SCIENTIFIC EXPLANATION FOR OUT-OF-BODY EXPERIENCES?

Imagine feeling as though you are floating above your body, looking down upon your physical self. Some argue that such out-of-body experiences (OBEs) prove that the conscious mind – or even the soul – can leave the body. Supporting this interpretation, people who have survived a near-death experience often recall experiencing this out-of-body sensation – as if their spiritual essence had separated from their corporeal existence.

However, the scientific explanation for OBEs is more terrestrial. Neuroscientists and psychologists believe it has to do

with neural processes going awry. In those who come close to death, such as cardiac arrest survivors, it is the lack of oxygen to the brain, and the release of certain neurochemicals triggered by trauma, that interferes with the sensory functions that support our usual feelings of embodiment. People's recollections of seeing themselves from above – such as observing surgeons working on their body – could be a form of hallucination or false memory, as they try to make sense of their experiences.

Consistent with the scientific explanation is the fact that OBEs are far more common among people with vestibular problems (the vestibular system is located in the inner ear and is crucial to our sense of balance and spatial orientation). Also, psychedelic trips, especially those associated with ketamine and DMT, can trigger OBEs, probably due to their effect on sensory processing in the brain.

What's more, researchers have induced out-of-body states in healthy volunteers simply by confusing their sensory systems. For instance, scientists at the Karolinska Institute in Stockholm asked volunteers to wear goggles that showed the perspective of a camera placed behind them (so that they could see themselves from behind). When a researcher prodded the camera with a baton at the same time as prodding the person's chest, the volunteer had the sensation that they were floating behind their physical body. The fact it is possible to induce an OBE argues against more mystical explanations. **CJ**

DOUGIE PARKER (AGE 6)

WHY DON'T I FEEL THE EARTH SPINNING?



If we are on a roundabout spinning quickly, we can feel a strange force that seems to want to throw us off. Our Earth is like a giant roundabout spinning in space at around 1,000km/h (as measured at the UK's latitude). So why don't we feel that same force really strongly? The reason is that there's another force acting on us: gravity. This holds us to the ground about 1,000 times more strongly than the Earth's spin is trying to throw us off. **RM**

STEVE PURVES, PRESTON

HOW DID PEOPLE SET THEIR CLOCKS BEFORE TV AND RADIO?

Time used to be determined using the position of celestial objects. The Sun was due south at midday, and the shadow of a sundial pointed due north. But the Sun isn't due south at the same moment everywhere. For example, it's due south in Bristol around 10 minutes after London. This became an issue with the development of railways in the 1830s, when clocks needed to be accurately synchronised over long distances in order to ensure passengers departed on schedule

and to avoid train collisions. The introduction of the electric telegraph in the 1830s ushered in the modern approach to synchronising clocks, in which precise time signals are sent to them at light-speed. Over the years, the railways managed to get towns to adopt a universal 'railway time' but some places refused to do so for years. In 1880 the entire UK was finally using the same time everywhere. **RM**



EXISTENTIAL FEAR OF THE MONTH...

A SOLAR STORM IS GOING TO TAKE DOWN THE INTERNET

Billions of tonnes of magnetised plasma are periodically ejected into space by the Sun's churning convection currents in the upper layers of its atmosphere. These 'coronal mass ejections' (CMEs) travel at speeds of up to 11,000,000 kilometres per hour, and the Sun can fire off as many as 20 per week, depending on where it is in its 11-year activity cycle. Although CMEs are common, they are launched in a narrow arc, and the chances of a large one hitting the Earth are relatively low. We had a near miss in 2012, but the last big strike was in 1859, before society became reliant on electricity.

If a CME on a similar scale was to strike the Earth today, it could damage the electronics

in orbiting satellites, disrupting navigation and communications systems, as well as the GPS time synchronisation that the internet relies on to function. It would also create a surge of electromagnetic radiation in the atmosphere, causing huge currents in our power grids which could burn out electrical transformers, leading to length outages. Without power, society itself would grind to a halt – not just the internet. But this is a worst-case scenario. Scientists monitoring the Sun would be able to give us a couple of days' warning of a dangerous CME, and in that time, vulnerable satellites could be shut down temporarily, and power grids reconfigured, in order to limit the disruption. *LV*



GETTY IMAGES X4 ILLUSTRATION: DAN BRIGHT

56

The percentage of UK wildlife that is in decline, according to the RSPB. The charity says that we have lost 40 million birds in the last 50 years, with cuckoos, turtle doves, skylarks and nightingales among those most at risk.

NATALIE RICHARDS, LEEDS

WHY DOES DRINKING ALCOHOL TRIGGER MY ANXIETY?

The psychological effects of alcohol are complex – it can have both sedative and stimulating effects on the brain, causing either sleepiness or physical arousal. How this manifests from a subjective perspective depends a lot on your mental state at the time, as well as the broader social context. While a drink can calm your nerves in some situations, lab research shows that it doesn't help reduce fear of a threat or predicament that you know is coming. If anything, because alcohol can enhance our focus on the present moment, it could trigger your anxiety by making you more preoccupied with whatever you're currently worried about. Alcohol can also accentuate anxiety by interfering with sleep and leaving you fatigued and feeling less able to cope. *CJ*



OLD WIVES' TALES...

CHEESE GIVES YOU NIGHTMARES

We're often told that eating cheese before bed gives you bad dreams, but there's little evidence to back this up.

The nightmares most likely result simply from eating late at night. While going to bed on a full stomach is never a good idea, studies show that eating fatty foods, such as cheese, just before bedtime gives us a lower quality sleep – and we're more likely to remember our dreams if we wake up a lot.

The link between late-night eating and nightmares is backed up by a Canadian study from 2015, in which psychologists questioned 396 students on their sleep habits. Almost half said that eating late brought on nightmares or disturbing dreams. Meanwhile, around 15 per cent believed that certain foods made their dreams more "bizarre or disturbing", with dairy foods the main culprits. However, the researchers point out that this belief could stem from years of being fed this old wives' tale.

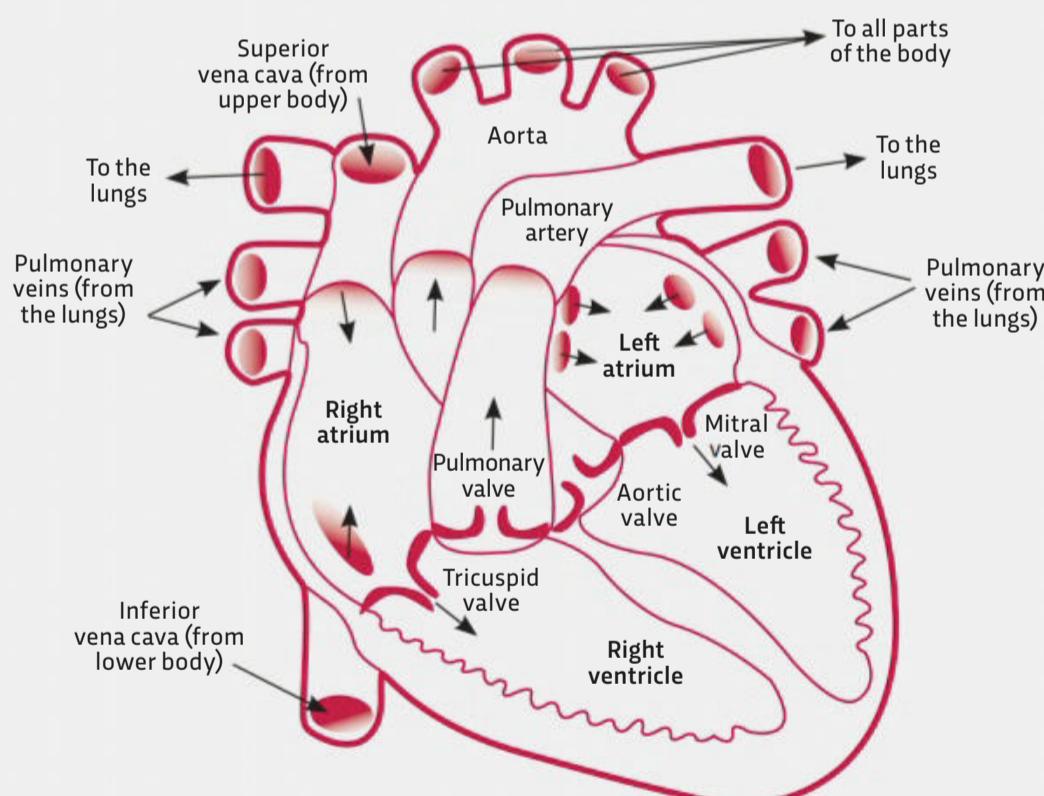
One theory linking cheese to nightmares points to a chemical in cheese called tyramine, which comes from the amino acid tyrosine. Tyramine triggers the release of the neurotransmitter noradrenaline in an area of the brain linked to dream sleep. But plenty of other foods with no reported nightmare links, such as chocolate, also contain tyramine, so there's a definite need for more proof on this one. ED



LORELY MASKELL

DO BIRDS FART?

Birds have an anus, and so technically could fart, but to date there's been no official evidence that they do. One theory is that they don't need to fart like humans and other mammals because they have a faster rate of digestion – their food simply doesn't spend long enough in their short gastrointestinal tracts to ferment and form gas. Another theory is that birds' guts don't contain the same gas-forming bacteria as mammals. It's also possible that ornithologists have missed bird farts because they leak out passively rather than in one eruption, or birds could be burping to release unwanted gas instead. CC



ADAM KING, HUDDERSFIELD

WHY IS THE HEART SLIGHTLY TO THE LEFT IN THE CHEST?

The heart is located fairly centrally beneath the breastbone, but it does protrude towards the left. This is because the heart's bottom-left chamber (the 'left ventricle') is responsible for pumping oxygenated blood around the whole body, so it needs to be stronger and larger than the right ventricle, which only pumps blood to the lungs. It's this left ventricle that you can feel beating in your chest. One in 10,000 people actually have a mirror-image heart which points towards the right – a condition known as 'dextrocardia'. HG

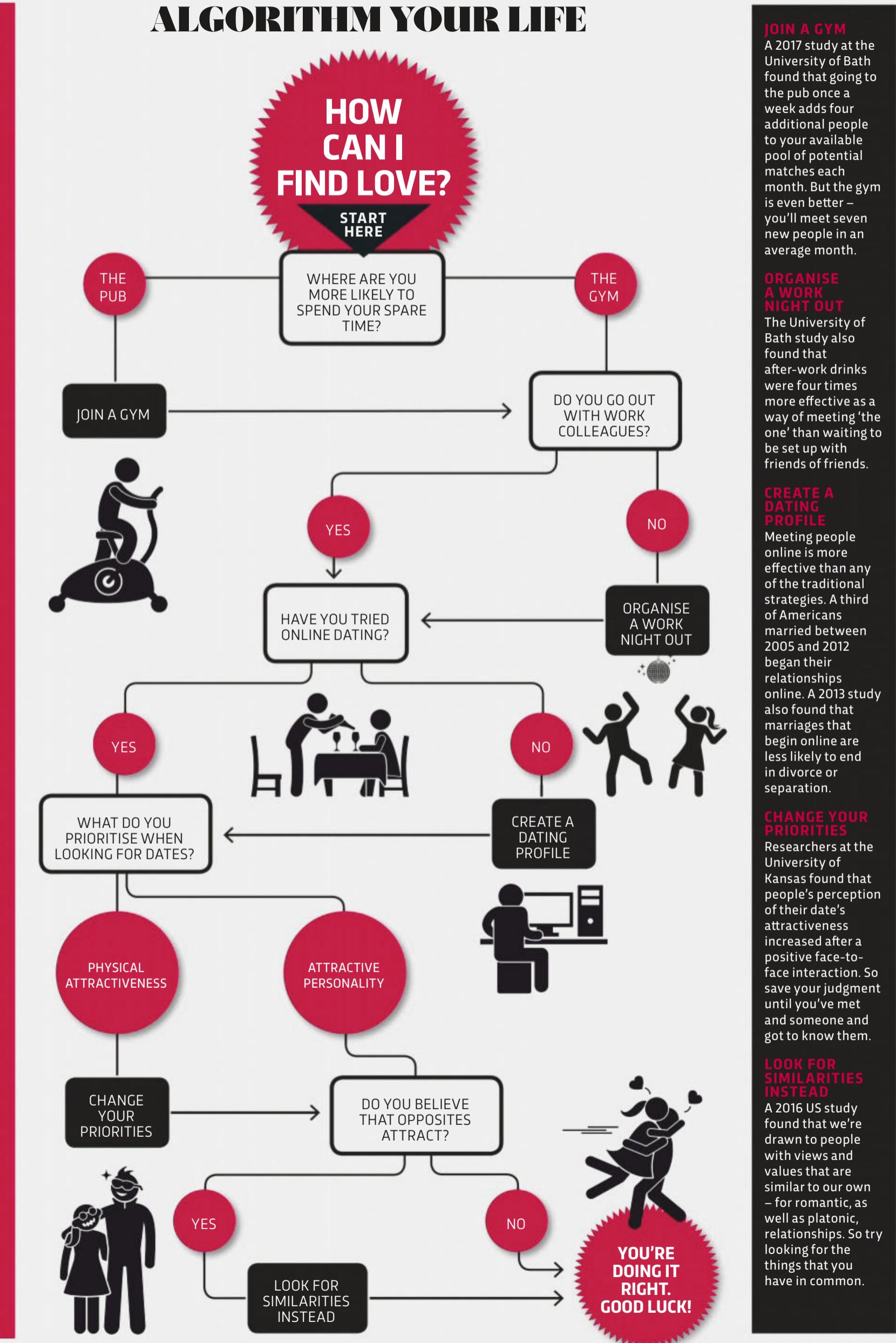
TALHAH LOONAT,
HANDFORTH

IS SPACE A PERFECT VACUUM?

A vacuum is defined as a space devoid of all matter. In the Solar System, space contains on average five atoms per 1cm^3 . Interstellar space, between stars, contains around one atom per 1cm^3 , while intergalactic space, between galaxies, contains 100 times less. Ultimately, a perfect vacuum isn't possible because quantum theory dictates that energy fluctuations known as 'virtual particles' are constantly popping in and out of existence, even in 'empty' space. **AGu**

NIGEL NGWENYA, LEEDS
WHY DOES ORANGE JUICE TASTE BAD AFTER TOOTH BRUSHING?

Toothpaste contains sodium lauryl sulfate (SLS) that creates bubbles when you brush. But it suppresses sweet receptors on the tongue, which prevents the brain from registering sweetness, and destroys compounds in the saliva called phospholipids, which block bitter receptors. So SLS not only cuts orange juice's sweetness, but promotes its natural bitterness, too. **ED**





DEAR DOCTOR...

DELICATE ISSUES DEALT WITH
BY SCIENCE FOCUS EXPERTS

I'M IN MY 30s AND I NEVER FOLLOW THE NUTRITION LABELS ON FOOD. AM I ABOUT TO DIE?

Probably not immediately, but you may be compromising your long-term health. That's because those colour-coded labels on the front of packaging – introduced by the government on a voluntary basis in 2013 – are a quick guide to the content of food widely held to affect health: energy (calories), total fat, saturated fat, total sugars and salt. Each is categorised red, amber or green depending on how they compare to so-called daily 'reference intakes' (RIs) set by the European Food Safety Authority. Admittedly, these aren't a perfect guide, though.

Take the RI for energy: 2,000kcal (kilocalories) per day. This figure is used across the board, but strictly it's the RI for a moderately active woman. If you're a very active man, for instance, you may be fine eating considerably more. Then again, scoff one biscuit per day that's rated 'green' for fat, sugar and salt, but which takes you just 50kcal above your optimum amount of calories, and in a few years you could go from slim to unhealthily overweight, as the body stores excess calories as fat. So while the guidelines are worth paying attention to, you'd also be wise to follow the advice of nutrition experts and swap the heavily processed and refined packaged food for more fresh vegetables, fruit, fish and nuts. RM

I HATE MY MASSIVE NOSE. WILL IT KEEP GROWING FOR THE REST OF MY LIFE?

Oh dear. Yes, your nose will keep getting larger, and your ears too. It's not so much that they're growing, but more sagging and becoming less elastic. In 2010, researchers at the University of Milan calculated that the total surface area of older people's noses (65-80 years old) is typically 15 per cent larger than that of younger people's (18-30 years old). The cartilage that shapes the nostrils and the tip of the nose loses its structure as we age, and the cartilage along the bridge of the nose starts to sag, too. But you can take comfort from a 2017 study, which found that people with bigger noses tend to be perceived as more intelligent. HG



MY BOYFRIEND HAS THREE NIPPLES. IS HE A MUTANT?



An extra nipple – or 'polythelia' to give it its scientific name – is relatively common. As many as 1 in 18 people have a third nipple, although this can range from one that is invisible on the surface, to a full nipple with milk-producing tissue. Most mammals have several pairs of nipples,

but as humans evolved to have smaller litters than other mammals, we lost all but our last pair. However, the genes to produce them are merely inactivated. A mutation in one of these genes causes a signalling protein called NRG3 to be produced, which can cause cells to develop into a third nipple. LV

BRIAN ASHLEY

MANY CLEANING PRODUCTS SAY THEY KILL 99.9 PER CENT OF GERMS. SHOULD I WORRY ABOUT THE REMAINING 0.1 PER CENT?

In most cases, you don't even need to worry about the 99.9 per cent. On hard surfaces, soap or detergent will remove enough germs for your immune system to cope with the few that sneak past. That's a strategy we're quite happy to adopt for the plates we eat off, so why should we need anything stronger for the kitchen floor? The 99.9 per cent figure is a fairly meaningless claim used by advertisers. Although it may be backed up by scientific tests, it doesn't tell us which strains of bacteria and viruses are killed, nor anything about the thoroughness of the cleaning procedure used in the original tests. Most bacteria are harmless to a healthy person in the quantities that we encounter on typical surfaces. And if you do need more antiseptic conditions, the thoroughness of your cleaning is more important than the 'kill percentage' on the bottle. LV

WESSLEY ALBERTS, NEW ZEALAND

IN WHAT WAYS ARE HUMANS MAKING THE EARTH LESS HABITABLE?



In quite a lot of ways, I'm afraid. Humans have thrived on the Earth for more than 200,000 years, but we have caused significant environmental damage – threatening the basic resources needed for the survival of our species, including water, air, soil and food.

By burning fossil fuels, we've sparked a rapid increase in global temperatures, which is predicted to cause a raft of issues from rising sea levels to more intense droughts and heatwaves. Intensive agriculture, deforestation and overfishing have damaged ecosystems and threaten many plant and animal species that we – and other species – rely on. We've contaminated our air and water with harmful gases, heavy metals, plastics and other pollutants. A growing population could exacerbate the problem. But all hope is not lost. Tangible solutions to slow or even halt these trends are within our reach. Clean energy sources promise to replace fossil fuels; more sustainable agricultural practices might ensure our planet continues to feed us; and less wasteful consumption could preserve precious resources such as water. **AFC**

DEXTER MIDDLETON, ORPINGTON

WHY IS SALTED CARAMEL SO ADDICTIVE?



It's official: we can never get enough salted caramel. A 2016 study at the University of Florida found that we eventually tire of foods that contain only one main recognisable flavour component – no matter how scrumptious. But the salty, sweet and fatty elements of salted caramel create a more complex taste that subtly changes with every bite, keeping our brains craving more and more. This is a phenomenon known as 'hedonic escalation'. LV

NATURE'S WEIRDEST CREATURES...

THE GOBLIN SHARK

ALAMY, GETTY IMAGES X3 ILLUSTRATIONS: DAN BRIGHT

Forget the great white shark from *Jaws* or the megalodon from *The Meg*: there's a new superstar shark in town, and it'll give you more nightmares than both of them combined. Meet the goblin shark.

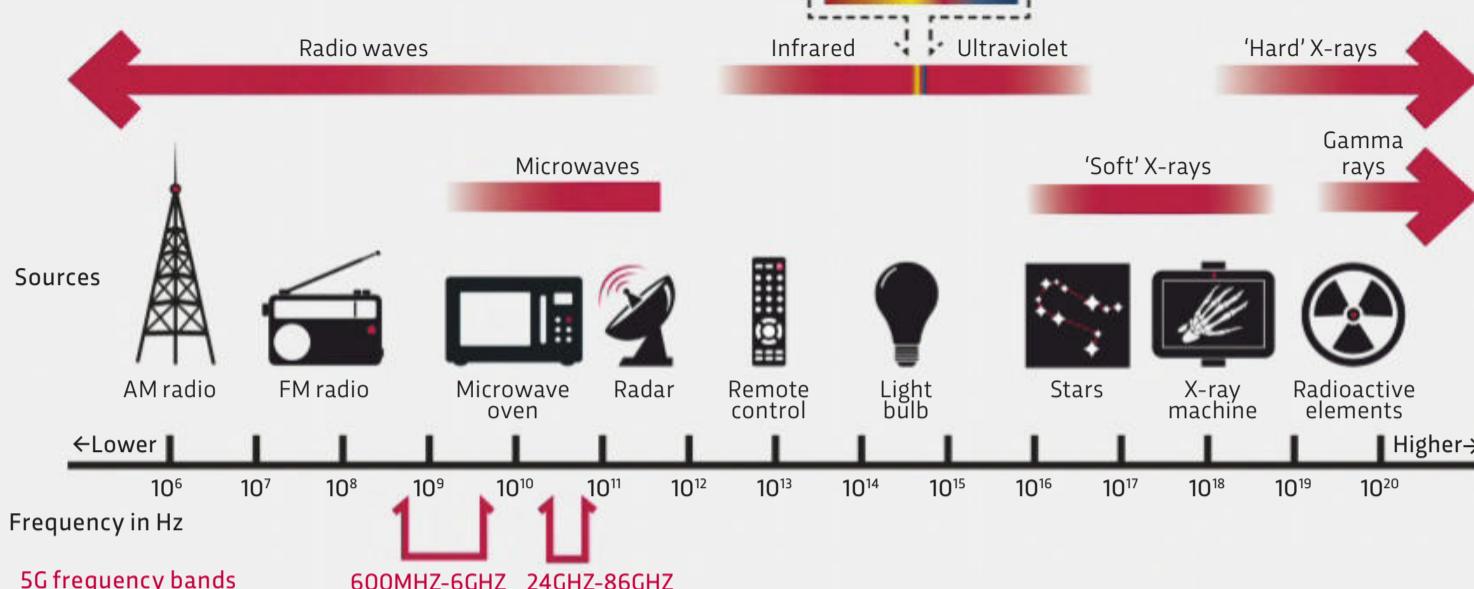
This secretive, four-metre-long fish was first found off the eastern coast of Japan, where it was described in 1898. With its unusually long snout and fleshy skin tone, the shark was given the name *tenguzame* – a reference to a mythical Japanese monster with a long face, pink skin and

demonic jaws, which led to the Western translation, 'goblin shark'. In recent years, rare video footage has shown just how incredible its jaws are. First, the goblin shark uses electroreceptors on its long nose to detect the electrical fields of fish. Then, when prey is located, it uses the natural buoyancy provided by its large, oil-rich liver to float silently towards it. When the unwary fish gets within range – SMASH! – a pair of extendable jaws filled with nail-like teeth lunge out from its face.

In every sense, the goblin shark is a creature ripe for Hollywood to exploit. Let's just hope that it doesn't follow in the path of many of its shark cousins and become exploited by fishing fleets, too. **JH**



TYPES OF RADIATION



SHAMMYCO, VIA TWITTER

IS 5G DANGEROUS?

The upcoming fifth generation of mobile networks, 5G, will use higher frequency radio waves than its predecessor, 4G. The new 5G will enable nearly 20 times faster data transfer than 4G. Radio waves are electromagnetic radiation. The higher the frequency of this radiation, the more energy is transferred, and the more potential it has to harm our bodies. Ultraviolet rays from the Sun are high-frequency and can be

dangerous. X-rays and gamma rays even more so. On the safer side of the spectrum, infrared radiation is lower frequency than visible light, microwaves even lower, and radio communication waves lower still – meaning less energy, and less potential to cause harm. 5G radio waves will have a maximum frequency of 86GHz, which is within the radio spectrum and is hence considered safe. **PB**

JOHN ECCLESTONE, GRIMSBY

WHATEVER HAPPENED TO 'STARLITE'?



In 1990, the BBC's *Tomorrow's World* featured a white, sticky coating with astonishing heat-resisting properties. In a demonstration, a raw egg painted with the stuff stayed raw in the heat of a blowtorch. Known as 'Starlite', it was the invention of a British amateur chemist called Maurice Ward, a hairdresser from Hartlepool who developed it after observing how some materials behaved in bonfires.

The TV demonstration sparked huge interest, with potential applications ranging from fire protection for skyscrapers to spacecraft heat shields. Tests by defence scientists in the UK and USA confirmed its abilities, but Ward would only give vague details of its composition, saying that it contained over 20 chemicals – mostly carbon-based – along with some ceramic material. Ward died in 2011, having failed to strike a deal with any manufacturer. An American company called Thermashield claims to have acquired the rights to Starlite in 2013, but to date it has not brought any products to the market. **RM**

QUESTION OF THE MONTH

LIANNE BUTTERWORTH, BROMSGROVE

COULD WE LAUNCH PLASTIC INTO SPACE TO REDUCE POLLUTION ON EARTH?

Launching plastic waste into space would be possible but far too costly. Estimates vary between £20,000 and £40,000 per kilogram for launching material into near-Earth orbit, and much more if we were to send it further away. This means that transporting the 300 million tonnes of

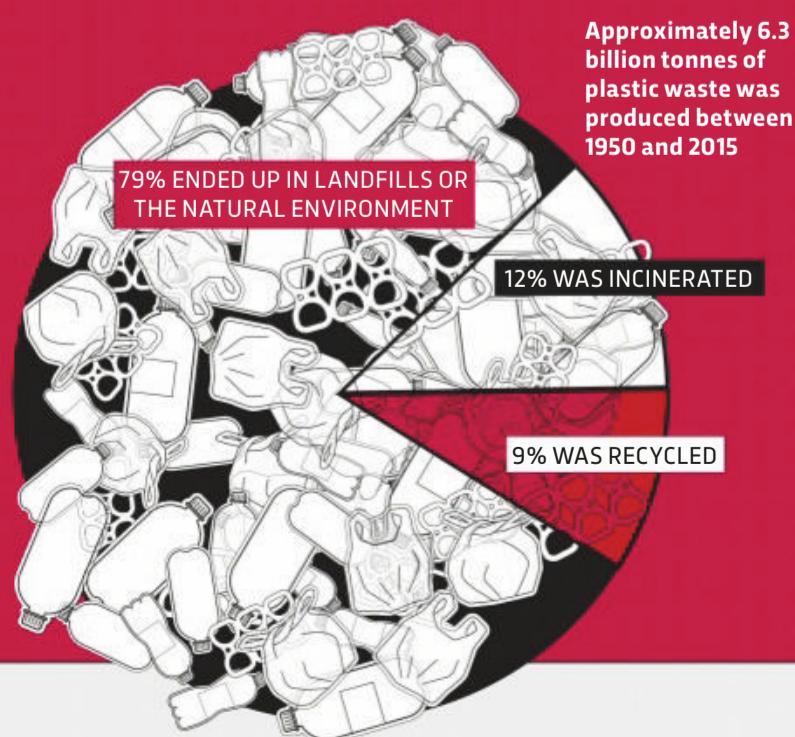
plastic waste we produce globally each year into space would cost at least £6,000 trillion yearly. The same material could be recycled for a fraction of the cost.

Furthermore, there's the ethical question of whether it is acceptable to dump our waste in near-Earth orbit.

Article IX of the UN Outer Space Treaty obligates nations to avoid the harmful contamination of space, so any such endeavour would require some form of international agreement, which would be difficult to obtain. **AGu**

WINNER

Lianne wins a Hang Around Bluetooth speaker from Jam Audio, worth £59. This compact, punchy speaker has up to 20 hours of playtime with its 30-metre Bluetooth range. Rugged and waterproof, it can handle the wildest parties in town (or just your in-shower karaoke). uk.jamaudio.com





DANIELLE BRANDON, DONCASTER

HOW DID PEOPLE MAKE ICE BEFORE FREEZERS?

For millennia, those rich enough got servants to gather snow and ice formed during the winter and stored it in straw-lined underground pits called 'ice houses'. But the ancient Persians stumbled across a neat bit of physics that allowed them to create ice from water even during the summer. At night, the Earth stays warm through the famous 'greenhouse effect', in which gases in the atmosphere help to trap the Sun's warmth. But on clear nights with low humidity, this effect is weaker, and objects can radiate their heat directly into space – a process called 'radiative cooling'. The Persians found that this allowed thin layers of water in purpose-built trenches to drop to a low enough temperature to freeze – even after hot days in the desert. RM

11

The rubbish, in tonnes, collected after 2016's London Marathon, much of it bottles.

This year, edible drinks capsules and compostable cups were trialled.

ROBIN THOMAS, NEWPORT PAGNELL

WHY ARE SOME ICEBERGS GREEN?

Most icebergs have a bluish tinge because the ice absorbs longer wavelengths of visible light (reds) better than shorter ones (blues), reflecting more blue light back towards our eyes. However, some Antarctic icebergs are a striking emerald green, and have long puzzled scientists.

The latest theory is that these 'jade bergs' are caused by iron oxide minerals in the ocean. As glaciers move over the Antarctic mainland, they scrape its rocky surface, producing powdered rock rich in iron oxides that's eventually carried into the sea. Scientists believe that pockets of the resulting iron-rich water then freeze onto the underside of icebergs, with the combination of orange-tinted iron oxide and blue ice producing a deep green hue. AFC

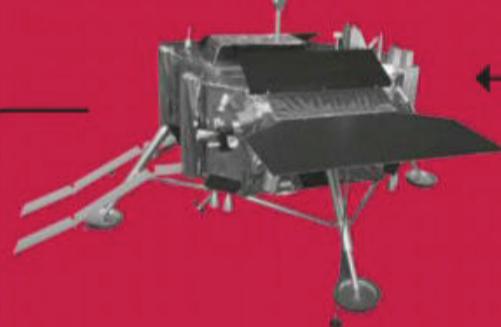


WHAT CONNECTS

PINK FLOYD AND POTATOES?



1. Pink Floyd's best-selling album was *The Dark Side Of The Moon*. There is no dark side, though: the hemisphere of the Moon facing away from Earth experiences just as much sunlight as the side that we see.



2. On 3 January 2019, China's Chang'e 4 lander became the first spacecraft to make a soft landing on the far side of the Moon.



3. It carried the 'Lunar Micro Ecosystem', a sealed 3kg cylinder containing insect eggs and seeds of various plants, designed to test whether they could successfully grow in lunar gravity.



4. Several of the seeds germinated, including some potatoes. The seedlings grew successfully for several days, until they eventually succumbed to the -50°C temperatures of the lunar night.

EMAIL YOUR QUESTIONS TO QUESTIONS@SCIENCEFOCUS.COM

'Funny, honest and heart-warming'

MATT HAIG

I'm a Joke and So Are You

Reflections on
Humour and
Humanity

Robin Ince

Foreword by Stewart Lee



**Are we more than our brains?
How can we deal with grief?
Should we laugh at offensive jokes?**

Robin Ince, comedian and co-presenter of *The Infinite Monkey Cage*, explores the fascinating (and often hilarious) mysteries of the human mind.

'A smart, laugh-out-loud book.'

Evening Standard,
Best Comedy Books of 2018

'Funny, honest and heart-warming.'

Matt Haig

'Moving and funny.'

Jo Brand

OUT NOW IN PAPERBACK



Discover Europe's Oldest
Operating Theatre (1822)
housed in the attic of St
Thomas' Church.



**THE OLD OPERATING THEATRE
MUSEUM & HERB GARRET**

www.oldoperatingtheatre.com

Open Daily: 10:30 AM - 5:00 PM
Admission Charge

RADAR

WHAT'S LIGHTING UP OUR ANTENNA THIS MONTH: CHELTENHAM SPECIAL



Come and join the BBC Science Focus team at one of the UK's most fascinating science festivals. Here's our pick of the week's talks. cheltenhamfestivals.com/science/

1. Moth-ematics
Moths and maths are vital to life, but both are misunderstood. Moth enthusiast Martin Coath and maths fan Katie Steckles tell us what maths can tell us about moths.

5 June, 5:15–6:15pm

2. Puzzles and pints
Wind down after a week of learning with puzzle-mad mathematicians Katie Steckles and Ben Sparks. Tinker with some puzzles, hints are available.

9 June, 6:30–8pm

3. Bakineering in space
Great British Bake Off finalist and engineer Andrew Smyth will take us through the links between baking and the engineering that keeps astronauts alive. Snacks included.

6 June, 5:45–6:45pm

4. Meals of tomorrow: our future food
Food scientist Marco Springmann and host Sophie Perry are transporting guests into the future with this scientific dining experience.

4 June, 4:45–5:45pm

5. Mental illness: what's to blame?
Writer Matt Haig, mental health researcher Praveetha Patalay and psychologist Suzi Gage discuss what's harming our minds, and how to break the cycle.

9 June, 4:30–5:30pm

6. Obesity: who is to blame?
Obesity has tripled since 1975. Geneticist Giles Yeo, psychologist Angel Chater and Angry Chef Anthony Warner debate whether it's us or the food industry that needs to change.

8 June, 1:45–2:45pm

The average age of Apollo 11's mission control team was 27 p93



200

Number of drawings by Leonardo da Vinci on display at the Queen's Gallery, to mark the 500th anniversary of the great painter's death p90



Profile

DRAWN IN BY LEONARDO

LEONARDO DA VINCI SURVIVES IN OUR MINDS AS A GREAT ARTIST, BUT HIS DRAWINGS SHOW THAT HE WAS ALSO ONE OF THE GREAT RENAISSANCE SCIENTISTS.

MARTIN CLAYTON, HEAD OF PRINTS AND DRAWINGS AT ROYAL COLLECTION TRUST, TALKS TO US ABOUT LEONARDO'S LEGACY.

MAY 2019 MARKS THE 500TH ANNIVERSARY OF THE DEATH OF LEONARDO DA VINCI. WHAT ARE YOU DOING TO MARK THE OCCASION?

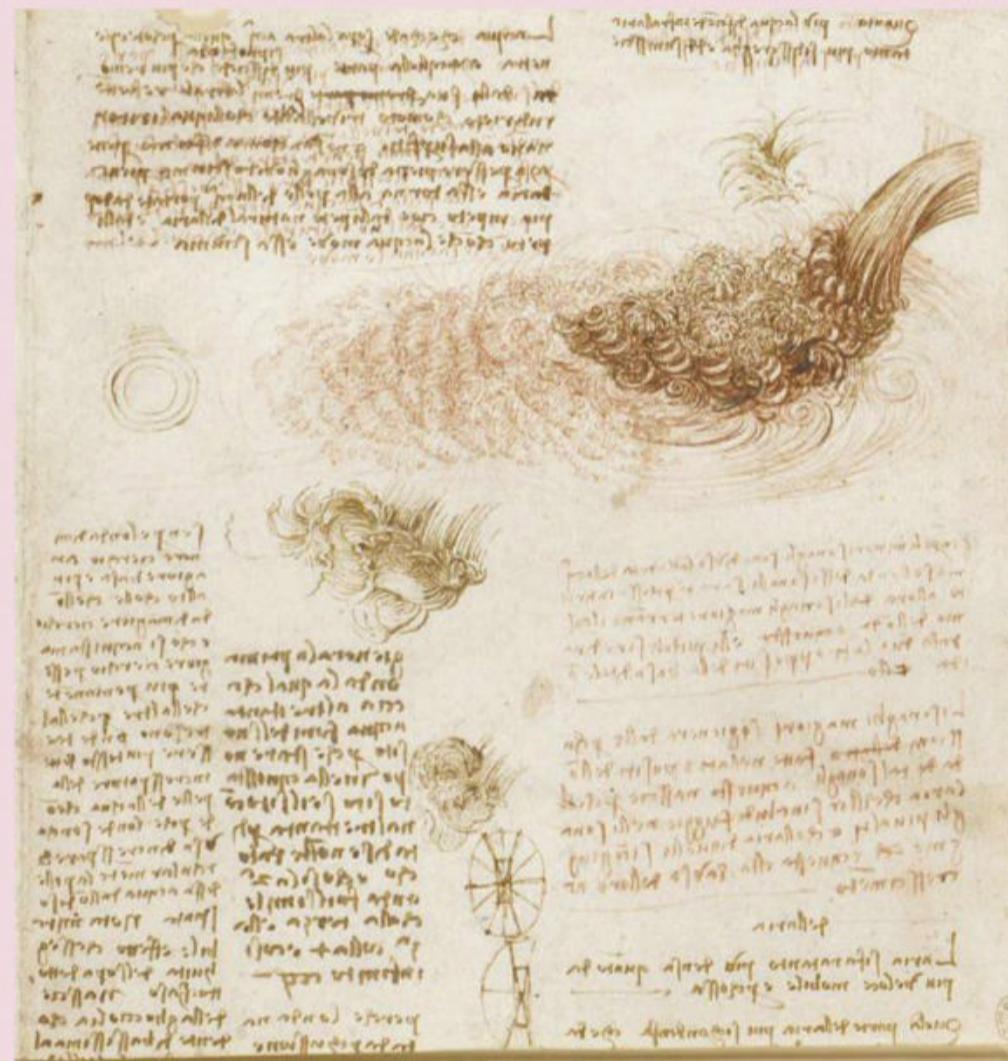
In the Royal Collection, we're fortunate to have the most important group of Leonardo's drawings to survive. It's more than 500 sheets that have been together as a group since Leonardo's death all those years ago.

In the summer we're having an exhibition of 200 drawings by Leonardo at the Queen's Gallery next to Buckingham Palace. We're hoping that it gives people an opportunity to see Leonardo's drawings in a way that they've never done before.

CAN YOU CONTEXTUALISE FOR US THE IMPORTANCE OF THESE DRAWINGS?

Drawing was central to Leonardo's work. It's the paintings that have survived today, but he was also a sculptor, an architect, an engineer and a scientist. But none of his sculptures survived, none of his architecture was maybe even executed.

His engineering seems mostly to have been designed, rather than built, and none of his



LEFT: *Studies Of Water*, by Leonardo da Vinci

RIGHT: *The Foetus In The Womb*, by Leonardo da Vinci

“He saw that the creations of the Universe and the creations of man were part of one, great harmonious whole”

science reached a conclusion that he was ready to publish.

But through the drawings, we get to know all these different fields of activity. We see in his drawings not just the preparations for his paintings, but also the preliminary works for his sculpture and architecture, so we can understand what he was working towards.

HOW DID SCIENCE INFLUENCE HIS ART?

Leonardo wouldn't have seen art and science as distinct areas of activity. He trained as a painter, and he soon came to the conclusion that painting was essentially a scientific undertaking;

that a painter should understand the physical structure of the Universe, the laws within which the Universe operated, the visual effects we can see, and that a painting should encapsulate all of those. A painter should therefore understand light, colour,

DISCOVER MORE

See more than 200 of Leonardo da Vinci's drawings at the Queen's Gallery, Buckingham Palace. 24 May – 13 October. rct.uk



perspective, proportion and anatomy, and all these different fields to be able to paint works that were true to life. Any scientist today will talk to you about the harmony of scientific laws, and how there's beauty in mathematics. That's exactly what Leonardo saw.

He saw that the creations of the Universe and the creations of man were part of one, great harmonious whole, and that to understand art and to understand science were essentially the same thing.

DOES HE DESERVE A PLACE AMONG THE GREAT HISTORICAL SCIENTISTS?

It's a double edged question, because if you look at his works, particularly in fields like anatomy, he is one of the great Renaissance scientists. He was making observations of a level of detail and insight that no other anatomist of the period was doing. However, he found it difficult to bring his work to a conclusion, so he never published his scientific work, and in science, publishing is everything. If you don't publish, if people don't know about your research, you may as well not have bothered.

It's impossible, therefore, to identify anything that Leonardo discovered that passed into general circulation. So while he was one of the greatest of Renaissance scientists, he had no impact on the field. And he's therefore a contradictory figure.

HIS SKETCHES OF THE AORTIC VALVES IN COW HEARTS FEATURE AT THE EXHIBITION. CAN YOU TELL US MORE ABOUT IT?

The functioning of the valves of the heart fascinated him, so he made a beautiful investigation in which he injected molten wax into the chambers of the bull's heart around the aortic valve, let the wax set, and dissected it out so he had a cast of the chambers around the aortic valve. He then made a gypsum mould around the wax cast, melted out the wax, and blew glass into the gypsum mould, so he then had a thin glass model of the chambers around the aortic valve. He then pumped water with a suspension of grass seeds through his little glass model, and observed the fluid flow. He saw vortices; little circular eddies of blood in the chamber beyond the aortic valve, and he

deduced that these eddies are responsible for opening out the leaflets of the valve and closing the valve after each pump of the heart. This was an extraordinarily astute observation. It was suggested again only in the early 20th Century, and confirmed through computer modelling in the 1980s. But Leonardo understood exactly how the valves closed.

AT THE END OF HIS LIFE, WHAT DO YOU THINK HE WOULD HAVE THOUGHT ABOUT HIS SCIENTIFIC CONTRIBUTION?

Towards the end of his life, he pretty much abandoned his scientific research. There was a mysterious episode in Rome where he was accused of something – we don't know what

in front of the Pope, some sacrilegious practices, and he was banned from further human dissection, which really seemed to take the wind out of his sails. For the next six years of his life up to his death in 1519, though he had all of his anatomical papers with him, he made no attempt, as far as we can tell, to structure them in such a way that they are able to be published.

These last five or six years of his life were marked by almost an abandonment of the scientific principles that he'd been working on over the last 20 or 30 years. He was, nonetheless, very keen to have his papers preserved for posterity, so maybe it's the case that Leonardo wanted someone to publish what he was unable to within his lifetime. But it was to be 400 years until that could happen, and by then any power that those drawings and notes may have had to influence their field had pretty much gone. The science had moved on.

I think that's how Leonardo would have seen his research, as something he knew he'd made great strides in, but he also knew it had ultimately come to nothing.

MARTIN CLAYTON

Martin is head of prints and drawings for Royal Collection Trust at Windsor Castle. Interviewed by BBC Science Focus editorial assistant Helen Glenny.

RECOMMENDED

FIND OUT WHAT'S CAUGHT OUR ATTENTION THIS MONTH



WHAT I'M READING

Helen Glenny

EDITORIAL ASSISTANT



MURMUR

BY WILL EAVES
 (£8.99, CB EDITIONS)

Murmur takes its inspiration from the last years of Alan Turing's life, starting with his arrest and conviction for gross indecency with another male. Turing's punishment was state-enforced chemical castration; a series of weekly injections with stilboestrol, a synthetic oestrogen, which altered both his body and his mind.

Turing predicted that "no doubt I shall emerge from it all a different man, but quite who I've not found out". In *Murmur*, Eaves explores these changes through the character Alec Pryor, a fictional representation of Turing. The first part of the novel is presented as Pryor's personal diary, in which he writes bursts of thoughts around his arrest, the beginning of his treatment, and his appointments with a psychoanalyst,

Eaves continues the story as a strange dream where Pryor is able to observe himself, both in present-day and in his childhood, punctuated by letters between Pryor and his friend June, a close confidante to which he was once engaged.

The book is a fascinating and feasible portrayal of Turing's thoughts, exploring things like sexuality, consciousness, agency and artificial intelligence. It's dense and quite strange, but at the same time it's a captivating interpretation of someone whose legacy is incredibly important.



WHAT I'M READING

James Lloyd

STAFF WRITER



THE HEARTLAND

BY NATHAN FILER
 (£14.99, FABER & FABER)

Schizophrenia is a word that is loaded with misunderstanding: images of violence and split personalities. Both are myths, and in this moving and compassionate book, author Nathan Filer offers a fresh look at the realities of this condition.

Filer is a qualified mental health nurse who first came to widespread attention with his debut (and multiple-prize-winning) fictional novel *The Shock Of The Fall*. The protagonist is a young man who's suffering with schizophrenia. This time, however the stories are real. *The Heartland* contains five vignettes which take us deep into the lives and minds of individuals who have been affected by the condition. Each account is no more than 30 pages long, but it's testament to Filer's storytelling that they pack more emotional punch than entire novels. There's pain and heartbreak in the details, but there's also humour and love and hope. Interspersed throughout the book are short essays exploring aspects of schizophrenia and mental health: the difficulty of making a diagnosis, the problems with chemical treatments, the fact that we're all susceptible to delusions and hallucinations. Filer brings new insight to even the most familiar topics: I was especially interested in his thoughts on why the current focus on reducing mental health stigma may be misdirected. One to share.



WHAT I'M LISTENING TO

Alice Lipscombe-Southwell

PRODUCTION EDITOR

13 MINUTES TO THE MOON

BBC SOUNDS
FROM 13 MAY

This July marks the 50th anniversary of the Apollo 11 mission, which saw the US successfully landing humans on the Moon for the first time. To commemorate the groundbreaking and dramatic event, the BBC is launching a new 12-part weekly podcast series on 13 May that captures the excitement of Apollo 11. The podcast is hosted by the ever-affable Dr Kevin Fong, who himself wanted to be an astronaut as a child. Perhaps that's why his enthusiasm is so tangible, as he takes us on a deep dive into the incredible technology and some of the unknown stories behind the achievement.



Over the course of the series, we find out how President John F Kennedy's 1962 speech galvanised a nation to get humans on the Moon within the decade. We meet some of the scientists, programmers and engineers who were involved with the mission,



including Michael Collins, who flew to the Moon alongside Buzz Aldrin and Neil Armstrong. But we also get to hear from some of the lesser known people, such as Poppy Northcutt, who was the first female engineer in an operational support role in Mission Control, and Don Eyles, one of the MIT programmers who wrote the software for Apollo 11's landing. We find out that the mission almost didn't happen: communications kept breaking down, the technology was stretched to breaking point, and tension in Mission Control was sky high. Despite this, the youthful workforce (the average age was just 27) overcame the struggles to beat the Russians to the Moon. The Moon landings took place a couple of decades before I was born, yet this series helped me grasp some of the excitement that gripped the world 50 years ago. The final episode airs on 20 July, the exact anniversary of the first Moon landing. Don't miss it.



WHERE I'M GOING

Sara Rigby

ONLINE ASSISTANT

DARK MATTER: 95% OF THE UNIVERSE IS MISSING

SCIENCE GALLERY, LONDON

6 JUNE – 26 AUGUST 2019

Everything you've ever seen – every single rock, plant and animal on Earth, every planet, star, black hole and galaxy – is comprised of ordinary matter, which makes up only 5 per cent of the Universe. There's an astonishing 95 per cent which no human has ever seen – or could ever see.

This 95 per cent is made up of dark matter and dark energy. Dark matter is crucial to the very structure of our Universe. Its gravity draws ordinary matter together to form galaxies, and these galaxies

cluster along dark matter's ghostly web.

But since dark matter emits no light or heat, despite knowing exactly where it is, we can never actually see it. So how can we humans, who rely so strongly on our sense of sight, ever hope to understand it? That's what the exhibition *Dark Matter: 95% Of The Universe Is Missing* aims to do by exploring the Universe's most mysterious component through art.

With Aura Satz's Dark Matter Radio, you can listen to dark matter, translated into sound from simulations. Meanwhile, Tomás Saraceno's Hybrid Solitary Semi-Social Instrument represents the cosmic web of dark matter with spider's web. As well as films such as *Mirror Matter* and *Through the AEgIS*, you'll find drawings, sculpture and even an evolving painting made from liquid crystals. It helps make dark matter a little more tangible!

Aerial view of CERN's Large Hadron Collider, which is helping particle physicists understand the Universe

Track your training

KEEP AN EYE ON THE
IMPORTANT, RELIABLE
VARIABLES WITH THESE
FINELY TUNED TRACKERS



HEXOSKIN SMART SHIRTS

These t-shirts and vests allow you to move away from using a wrist-based tracker. They'll record the basics like heart rate (which has been clinically validated) and GPS data, and a tonne of other metrics, like breathing rate, ECG, acceleration and exercise intensity.

FROM \$399 (£310 APPROX), HEXOSKIN.COM



SUUNTO 9

The Suunto 9 takes care of everything you might possibly need from a watch, with a price tag to match. It combines GPS and motion sensors for super-accurate distance tracking, uses a barometer to track altitude, predicts the weather, reads your heart rate, and has customised modes for more than 80 sports.

£625, SUUNTO.COM



COROS PACE

Designed for triathletes, this watch focuses solely on the important variables; it measures heart rate at the wrist, give you information on heart rate zones, includes a highly accurate GPS, and tracks sleep. It's optimised for fitness but hasn't packed in any unnecessary features, and as a result it lasts almost a full day when GPS tracking, around double that of its competitors. Its associated app collects your training data, pooling your workouts across time so you can track your progress.

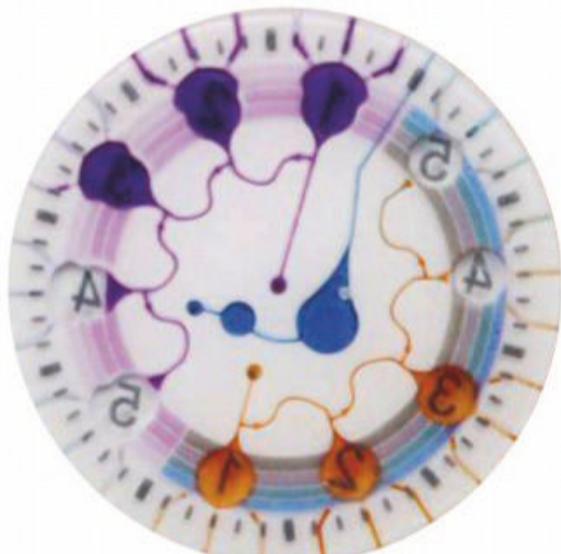
£250, COROS.COM



MOOV HR SWEAT

Moov's adored for making no-frills, affordable tracking devices. You can watch them test their new heart-rate tracking headband against an ECG on their website; the results make this wearable look seriously reliable.

\$49.99 (£40 APPROX), MOOV.CC



EPICORE BIOSYSTEMS MICROFLUIDIC SENSOR

These wearable adhesive sensors sample the biomarkers in sweat, allowing athletes to track sweat rate and electrolyte loss in order to stay perfectly hydrated. They're still being tested in the lab at the moment, but could soon be consumer-friendly.

NOT YET FOR SALE, EPICOREBIOSYSTEMS.COM

Troubleshoot

MONITORING WHAT MATTERS



MODERN FITNESS TECH COMES PACKED WITH FEATURES. EXERCISE PHYSIOLOGIST JONATHAN PEAKE TELLS US HOW SOME OF THESE TRACKERS WORK

WHY WEARABLES?

I have a keen interest in methods for monitoring stress in athletes, and that's where my interest in health and wearable technology comes in; understanding how they work, whether they've been validated, and whether they agree with gold standard technology.

HOW DOES VALIDATION WORK?

There's no standardised method, but a comparison to gold standard is the best way to go. Some Fitbit devices allow you to monitor sleep patterns and sleep quality, so the comparison there would be to send someone to a sleep clinic. You'd hook them up to cables to monitor brain activity, and also give them a Fitbit device to wear. You'd compare the two to see the level of agreement. For a heart rate monitor, you'd compare it with a 12 lead electrocardiogram (ECG). Getting products tested independently is important as well, to avoid conflicts of interest.

WHICH VARIABLES CAN IMPROVE SOMEONE'S EXERCISE ROUTINE?

I think there's plenty to be gained by measuring basics like step count, distance, heart rate, and heart rate variability. Heart rate monitors are a

well accepted part of an athlete's toolkit. Now we've got more advanced smartwatches which provide GPS information, and data about time spent in different heart rate zones. That's useful and well accepted within the exercise physiology community and that information has been validated.

Newer technologies measure the variation in the time between heartbeats, which is called heart rate variability. They use that to calculate a recovery index, which tells you when you're ready to train again. That's good in a way; it gives you a nice indicator. But it's based on data that's been oversimplified. A lot of assumptions and shortcuts are built into these types of devices, but most of the public are happy to settle for that compromise, even though they might be getting slightly inaccurate information.

HOW DO THESE SHORTCUTS WORK?

Heart rate variability is probably the best example. Heart rate variability gives you a window into your autonomic nervous system, which can be divided up into your parasympathetic nervous system – rest and digest – and the sympathetic nervous system which is the fight, flight or fright branch.

When we exercise, the sympathetic nervous system dominates, because the heart needs to beat fast to deliver oxygen around the body. During recovery we're aiming to flip the switch and promote more parasympathetic activity, so the body's various different systems can take care of repairing tissues and restoring the various different physiological systems.

There are at least four or five different metrics that exercise physiologists derive from heart rate data, but wearables simplify this information for the user by generating a 'recovery index', which is based roughly on the balance between sympathetic and parasympathetic activation.

WHICH VARIABLES AREN'T USEFUL?

Some measurements coming through probably require a fair bit more validation, explanation and interpretation for the user. Some wearables



"There's plenty to be gained by measuring basics like step count, distance, heart rate"

monitor environmental information and hydration status. There are patches that you can strap to your body, which have been developed with quite a lot of technology and science behind them. They sample small drops of sweat and pass them through a microfluidic system, which measures electrolyte levels and gives you a readout on your hydration status. There's still some way to go before that becomes a user friendly thing. The same goes for blood oxygenation levels.

HOW CAN WE BEST USE CONSUMER EXERCISE PRODUCTS?

It's valuable to track exercise intensity and recovery bearing in mind the shortcomings and assumptions that go with the data those watches provide as well as training loads and distances. Some high end watches can be connected to second or third party software that analyse your training in more detail. Putting aside issues around accuracy and validity, if people are using wearables consistently, then they can generate specific, personalised information. I don't think there's a lot of value in comparing your own data against other people or population norms, but you can monitor your own data across time, which can be quite powerful.

DR JONATHAN PEAKE

Jonathan is an exercise physiologist at Queensland University of Technology. Interview by BBC Science Focus editorial assistant Helen Glenny.

DISCOVER MORE

SQUEEZE EXTRA JUICE OUT OF THE TOPICS IN THIS ISSUE OF *BBC SCIENCE FOCUS* WITH THESE BOOKS, WEBSITES AND SHOWS

Reality check p28

HISTORIANS USE LASERS TO UNLOCK MYSTERIES OF GOTHIC CATHEDRALS

Watch Andrew Tallon capture the details of a cathedral in Washington DC using the same laser scanning method he used in Notre-Dame.

bit.ly/notre_dame_lasers

MEET THE BIOHACKERS

These 'biohackers' are trying to optimise their lives by inserting technology under their skin, radically changing their diets, or trying to create an entirely new human species.

bit.ly/bbc_biohackers

BIOHACKING

Prof Jonathan Ball explores gene hacking technology to see just how easy it is to edit the human genome.

bit.ly/radio4_biohacking

No more pain p42

FROM AGONY TO ANALGESIA

Irene Tracey, a professor of neuroimaging, explores the science of how we see pain in the brain and body and how we treat it.

bit.ly/bbc_agony

THE OTHER SIDE OF HAPPINESS: EMBRACING A MORE FEARLESS APPROACH TO LIVING

BY BROCK BASTIAN
 (£9.99, PENGUIN BOOKS LTD)

An intriguing read that makes the argument that in today's world we guard ourselves from experiencing pain, difficulty, and risk to the detriment of our happiness. Drawing on psychology and neuroscience research, Bastian argues that people are happiest at the "knife-edge between pleasure and pain".

Angela Saini interview p48

SUPERIOR: THE RETURN OF RACE SCIENCE

BY ANGELA SAINI
 (£14.99, HARPER COLLINS)

Angela's book explores the persistent belief that there is a biological difference between the races.

YOU, ME AND EUGENICS

BBC FOUR, OCTOBER

This programme, presented by Angela Saini and Adam Pearson, explores the history of eugenics. They also investigate eugenics' modern iterations, and find out about breeding a 'better' human.

SCIENCE FOCUS PODCAST: INEQUALITY IN SCIENCE

Last year, we talked to Angela about what science tells us about the differences between men and women, and why women have historically been excluded from science.

bit.ly/inferior_angela_saini

INFERNIOR: HOW SCIENCE GOT WOMEN WRONG

BY ANGELA SAINI
 (£9.99, HARPER COLLINS)

Angela shows how science has contributed to the deeply-rooted preconceptions about the differences between men and women.

Radar p89

LEONARDO DA VINCI'S DRAWING MATERIALS

Find out exactly how Leonardo da Vinci was creating his drawings in the late 1400s and early 1500s in this video from the Royal Collection.

bit.ly/drawing_materials

The fight against deepfake p64

DEEPFAKES AND THE TECHNOLOGY BEHIND IT

In this video, BBC Click investigates the software used to swap presenter Spencer Kelly's face with Donald Trump's.

bit.ly/bbc_deepfakes

Life on Mars p70

NASA SCIENCE MARS EXPLORATION PROGRAM

This interactive site provides a brilliant overview of the space agency's Mars missions past, present and future. It's updated with pictures from the Red Planet, the latest findings and best of all the current weather up there (at time of writing it was a balmy -21°C).

mars.nasa.gov

CURIOSITY ROVER'S TWITTER ACCOUNT

Accounts like these keep us on the social network. Follow the Martian wanderer to see some incredible photography taken on another world. @NASAsight and @ESA_ExoMars are brilliant too.

twitter.com/marscuriosity

FOR MORE, FOLLOW US

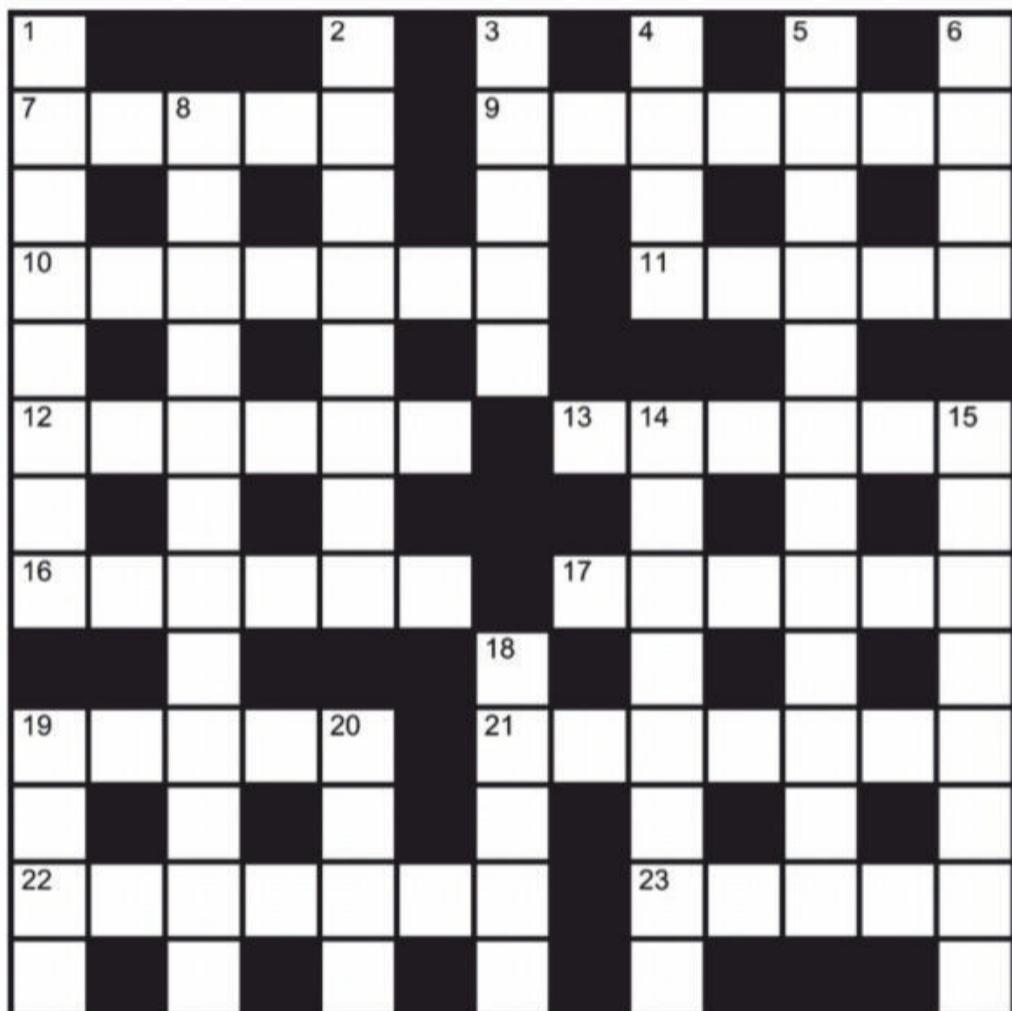


@SCIENCEFOCUS

NEXT ISSUE

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

- 7 Quiet fellow, when put in stage (5)
- 9 Ground for turtle to lose fifth of carapace (7)
- 10 Waving a rag in stupid sketch (7)
- 11 City of high entertainment (5)
- 12 Amused about a monster (6)
- 13 Copper, say, has Everton final in mind (6)
- 16 Painter's at it, boxer's on it (6)
- 17 Expert on alien food (6)
- 19 Concentrate on what a lens does (5)
- 21 Perusing place in Berkshire (7)
- 22 I would back putting cover around split (7)
- 23 Finished on time, that's obvious (5)

DOWN

- 1 Record one medic spreading outbreak (8)
- 2 Banks are sadly in a state (8)
- 3 Society thanks politician for part of postal service (5)
- 4 Draw around top of reed basket (4)
- 5 Obvious, leaving diamonds in place of copyright (6,6)
- 6 Insect of biting nature (4)
- 8 A boy can dive about around small treasure trove (8,4)
- 14 Teacher trained our cadet (8)
- 15 Go to court, reaching illuminated entrance around one (8)
- 18 Sign of tooth decay not having started (5)
- 19 Four notes, diminuendo (4)
- 20 Balance on board wearing furs (4)

GETTY IMAGES

A N S W E R S

For the answers, visit bit.ly/BBCFocusCW

Please be aware the website address is case-sensitive.

COVER STORY

DINOSAURS IN COLOUR

What can new technology reveal about the lives of these ancient creatures?



PLUS

THE HUMAN HIBERNATORS

Meet the people who have a brain disorder that causes them to sleep for 20 hours a day, for weeks on end.

ALIEN ATMOSPHERES

Scientists are recreating exoplanet atmospheres inside the lab. We find out what their work could tell us about these distant worlds, and the possibility of finding life there.

ON SALE 19 JUNE



A SCIENTIST'S GUIDE TO LIFE

THE GIFT OF THE GAB

WHAT'S THE BEST WAY TO DEAL WITH COLD CALLERS AND WIN AN ARGUMENT?

ELIZABETH STOKOE,
AN EXPERT IN SOCIAL
INTERACTION, REVEALS ALL

HOW CAN I HAVE BETTER CONVERSATIONS?

First, understand what counts as 'better'. A better conversation is one where there is minimum friction, misunderstanding and repetition, and maximum alignment between both parties. Some people are naturally good conversationalists, others less so. My job is to collect conversations from 'the wild', and then analyse them to see what's effective and what isn't.

WHAT MAKES A GOOD COMMUNICATOR?

I think people who are good at communicating are also good at listening. They can see what the other person is doing and fit their responses to it. They open up slots for people to make productive contributions. I research police crisis negotiations with my colleague Rein Sikveland. If a negotiator is talking a suicidal person down from a ledge, what works is opening up slots in the conversation so the person in crisis can decide to come down. A good negotiator makes it possible for someone in crisis to show they're deciding things for themselves.

IS THERE ANYTHING THAT I SHOULD AVOID DOING?

Avoid starting conversations with

challenging or aggressive statements. I once had a neighbour whose opening shot when I left the house was, "You left your bins out." It immediately catches you on the wrong foot. Don't point it out [their challenge] overtly, or they might feel like they're the victim. One thing you can do is just give a lengthy beat of silence and look at them, or you can take the heat out of the situation and say, "Hello." This is what belongs at the start of a conversation.

HOW SHOULD I DEAL WITH COLD CALLERS?

You have to remember that this is a difficult job. They spend their days dealing with people who don't want to talk to them. Think about it empathically. If you don't recognise the number, you can choose not to answer the call. If you do pick up, you can ask early on, "Is this a sales call?" Be concise, but be nice.

WHAT TECHNIQUES CAN HELP ME TO WIN AN ARGUMENT?

First, distinguish between the arguments that do and don't matter. Let the small stuff go, and remember it's good for humans to challenge each other sometimes. If you do need to voice your disagreement, try to disagree in a good way. For instance, if someone says, "Ooh, I hate the BBC," and you want to remain in alignment with that person, while being true to your view that the Beeb is great, then start with a weak agreement. "Yeah, it can be stuffy sometimes, but I love it." You've made a concession and attended to a potential problem, but maintained your own view.

HOW CAN I SHUT PEOPLE UP?

Make a small noise, like "Ah..." then cut it off and withdraw. It shows people that you're trying to join in, but it also lets them continue for a moment. A decent human being will recognise that you want to speak! SF

NEED TO KNOW...

1

Don't start conversations with aggressive statements.

2

Be nice to cold callers. Or just don't answer the phone.

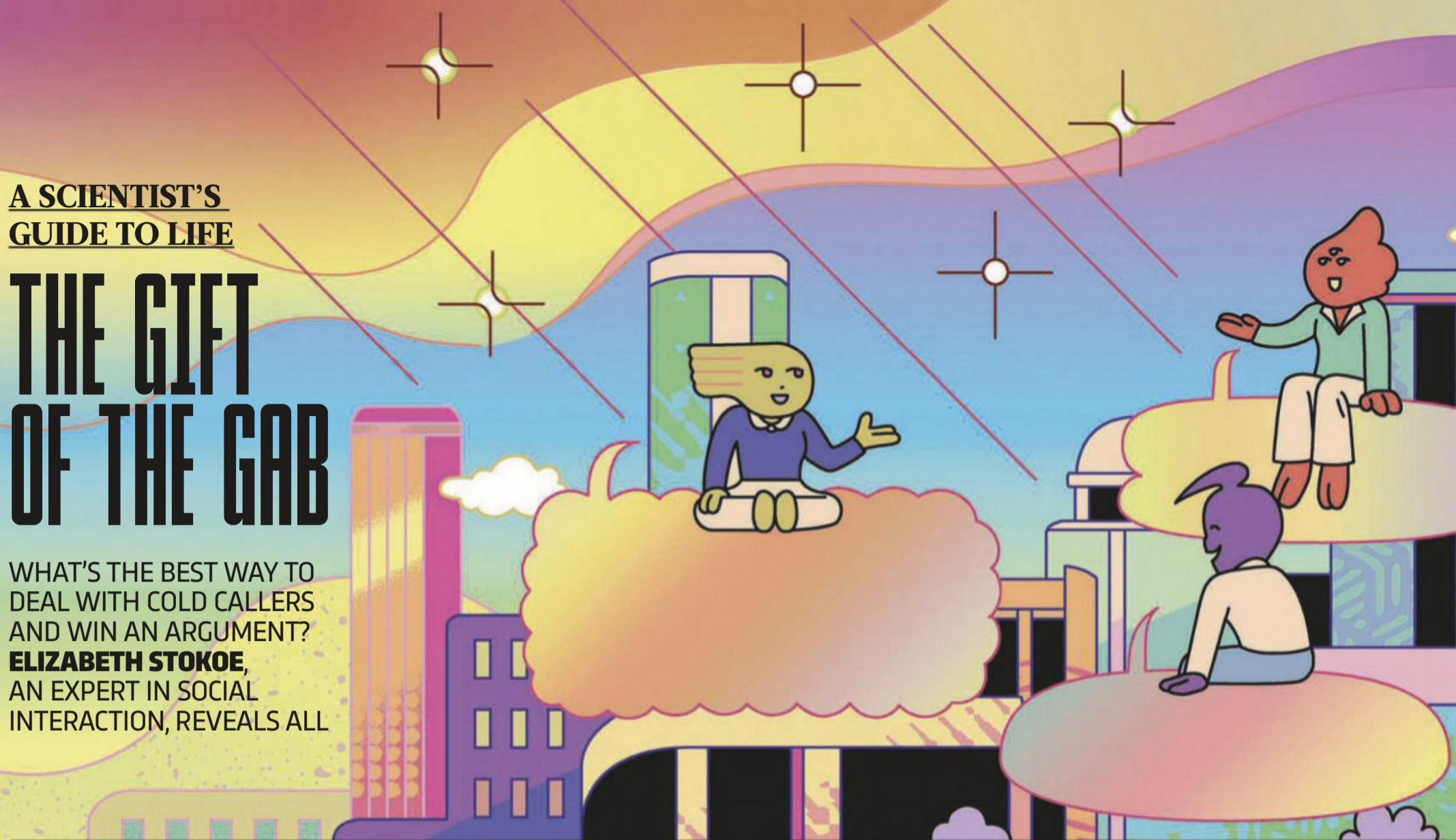
3

Distinguish between arguments that do and don't matter, and let the small stuff go.

ELIZABETH STOKOE

Elizabeth is a professor of social interaction at Loughborough University. She's the author of *Talk: The Science Of Conversation* (£14.99, Little, Brown & Company).

Interviewed by Dr Helen Pilcher.



FROM THE
MAKERS OF

BBC
Sky at Night
MAGAZINE



THE APOLLO STORY

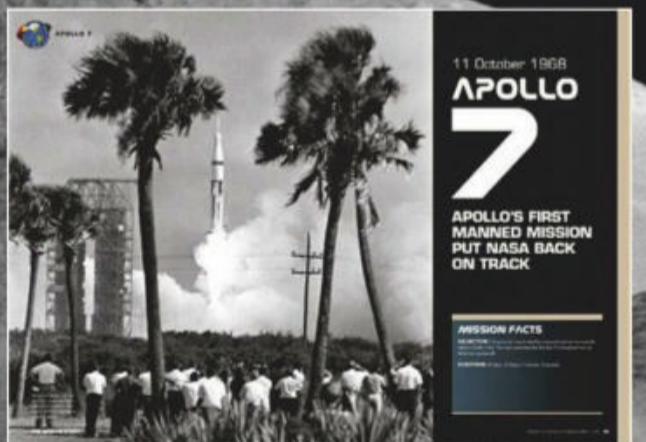
BBC Sky at Night Magazine brings you *The Apollo Story* – your complete guide to the greatest journey in human history.

The story begins with the tragic fire that killed the crew of Apollo 1, continues through Neil Armstrong's first steps on the Moon, and ends as the cost of space exploration halted the programme at Apollo 17.

Packed with all the facts, figures and stories from each and every Apollo mission, as well as rare photographs, this new special edition tells the full story of this giant leap.

BBC Science Focus subscribers receive FREE P&P on this special edition

Chris Bramley,
Editor, *BBC Sky at Night Magazine*



The full story behind every Apollo mission, including many rare and revealing photographs. Every mission is unique and extraordinary.



Go behind the scenes to learn how the astronauts ate, slept and coped with almost two weeks in space. What was it really like to go to the Moon?



Every mission is covered in full detail, with all the facts, figures, crews, stats and dates. Even the mission badges are looked at.

ORDER YOUR COPY TODAY

visit: www.buysubscriptions.com/apollo2019

Alternatively call 03330 162138[†] and quote 'THE APOLLO STORY 2019 PRINT1'

TUK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff).

Outside of free call packages call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Monday to Friday 8am–6pm and Saturday 9am–1pm.

*Subscribers to BBC Science Focus receive FREE UK POSTAGE on this special edition. Prices including postage are: £11.49 for all non-subscribers, £12.99 for Europe and £13.49 for the Rest of World.

All orders subject to availability. Please allow up to 21 days for delivery.

CATCH THE SUMMER LIGHT
WITH NIKON

INSTANT
SAVINGS



Photographer: Alina Rudyia

SAVE TODAY



CAPTURE TOMORROW

Get instant discounts on selected Nikon cameras and NIKKOR lenses.

Save today! Offer available from **15th May 2019 until 15th August 2019**.

For details on the range of products available and T&C please visit nikonpromotions.co.uk
Available at participating retailers.

